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EDITORIAL

REPORT OF MEDICAL ARTICLES IN THE LAY PRESS

No matter how much they may pretend indifference, doctors are surely bound to be affected by and concerned with reports of their activities by the Daily Press. If these activities are considered shameful, then the press report contributes a very great deal to the punishment of the miscreant. Honour and reputation are the staff of life for medical men. If the reports are agreeable, perhaps of new developments, of research or the first announcement of possibly important therapeutic advances, then the medical man or men concerned will be anxious as to the reactions to the publicity of his colleagues and in particular of the Medical Council. If given the opportunity he will require from reporters making personal enquiry, strict anonymity.

There is, however, one source of information available to "our Medical Correspondent" which cannot be denied him. This is the Medical Press. Frequently reports of articles in medical journals appear in the lay press even before the publication has been seen or indeed received by the doctor. Names are mentioned and the reports are sometimes made as sensational as possible—the degree of this will depend upon the policy of the newspaper making the report. Anonymity, of course, goes by the board.

There seems to us to be three possible results. Firstly, the loss of the doctor's anonymity may cause him pleasure, embarrassment and/or anxiety. It is, to say the least, doubtful that this type of publicity does good to anybody, and is probably regarded generally as undesirable. Secondly, the reports may raise the hopes of sufferers from various conditions of cures which may only be tentative and are likely to require further investigation. Doctors may be plagued with demands for the new treatment. A third and even more serious point, however, is that sensational reports may create real and widespread alarm; there are many instances where this has undoubtedly occurred. In two recent cases the reports were taken from the Medical Press. In one the alleged dangers of "laughing gas" were emphasized, and in the other attention was drawn to the possibility of a patient being awake during operation. Whether these reports were accurate or not is not the point to which we wish to draw attention. The distressing feature is the great harm that may have been done. Patients are already sufficiently apprehensive sometimes to make them loath to consult a medical man or dentist until the disease has progressed perhaps to a point beyond a simple remedy. Their anxiety will only be aggravated by publicity of this nature. It cannot be claimed that the Press is drawing the attention of doctors to the position; that is already done by the Medical Press.

It is not too fanciful to foresee the time when doctors will be wary of reporting their failures or their accidents, even though we all know such reports may prevent many future disasters.

We appeal to the Press to co-operate with us in allaying unnecessary anxiety and apprehension by a more judicious use of their great power.

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ATELECTASIS: ITS EVOLUTION DURING UPPER URINARY TRACT SURGERY

BY

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IN recent years many studies referring to the various effects of different positions which the patient is required to assume on the operating table have been undertaken (Attinger et al., 1956; Brown, 1948; Case and Stiles, 1946; Dripps and Severinghaus, 1955; Eather et al., 1949; Faulconer et al., 1946; Henschel et al., 1957; Slocum et al., 1947; Sokalchuk et al., 1949). Blood pH, arterial oxygen saturation and carbon dioxide levels have frequently been shown to be altered in the patient who is breathing spontaneously. These investigations have generally been concerned either with cardiovascular derangements, or with the limitation of ventilation imposed by various positions on the spontaneously breathing patient. The effect of controlled respiration in other than the supine position has, however, not been fully examined.

In agreement with Faulconer et al. (1946), it is our experience that atelectasis of the lower topographical area of the lower lung frequently occurs during upper urinary tract surgery. It was considered worth while to investigate the mechanism of its evolution, since such an understanding could then be applied to prevent or at least mitigate this complication in the patient lying in the lateral nephrectomy or jack-knife position.

It has been shown that in this lateral position the effect of gravity upon the mediastinum reduces the lower lung's volume; similarly, the movements of the thoracic cage are impaired in the lateral position. Since posture influences the diaphragmatic and costal elements of respiration and the lung volumes so significantly, it may be assumed that the same factor will influence ventilation. Lung volume changes are, however, not always closely correlated with gaseous exchange in the lung. Compensation for these volume changes occurs by increasing oxygen uptake (Svanberg, 1957) and carbon dioxide elimination and an increased diaphragmatic movement in the lower hemithorax (Zoltan, 1958). An indissoluble partnership exists between the circulatory and respiratory systems, and it may be said that the lung volumes are only the boundaries within which ventilation takes place (Donald, 1953).

In the lateral position the absolute oxygen uptake from the lower lung is greater than that from the same lung in the sitting or supine position. When compared with the measurements noted in the supine position the lower lung in the lateral position increases its oxygen uptake by about 6 per cent. In the right lateral position the dependent lung would thus be responsible for 59 per cent of the total oxygen uptake against only 47 per cent in the left lateral position (Svanberg, 1957). It is apparent then that in both lateral positions the relative alveolar gaseous exchange of the lower lung, when measured bronchospirometrically, is somewhat larger than its share of the tidal volume can be expected to provide.

This might be explained by the assumption that the deadspace effect in bronchospirometry is somewhat larger in the upper lung with its decreased ventilation and its increased volume. Such is borne out by the conclusions of Rossier and Bühlmann (1955) who state that the deadspace, as conventionally measured, represents a "function" much more than it does a "volume". (It is an over-simplification to assume that alveolar ventilation is merely the tidal volume less the anatomical deadspace (Comroe, 1954).) In the spontaneously breathing patient a change in posture need not in itself imply any hyper-

or hypoventilation of one or the other lung. Despite the changes in lung volumes and ventilation, due to posture, a balance is apparently maintained between these two factors, resulting in an unchanged composition of the alveolar air, as collected from the trachea, and the arterial gas tensions.

During spontaneous respiration in normal people in the sitting position, a uniform distribution of inspired gas and pulmonary blood flow is generally assumed (Bates et al., 1954; Bates and Pearce, 1956; Briscoe et al., 1951; Nunn, 1957). Blair and Hickam (1955), however, have demonstrated an unevenness in the distribution of naturally inspired gases. These investigators distinguish two ventilatory phases; a minor part of the lung, 20–30 per cent, is hyperventilated and the remainder is slightly hypoventilated. These hypoventilated parts were termed "slow spaces". Changes in body position resulted in a significant alteration in the size and ventilation rate of these hypoventilated areas, the location of which could not be determined. Blood perfusing such regions would be poorly aerated, resulting in a venous admixture effect.

Furthermore, it has been shown, by simultaneous measurement of the end-expiratory alveolar gases from basal and upper lobar bronchi of the same lung, that lobar differences in their composition do exist (Martin et al., 1953; Mattson and Carlens, 1955), and that these differences can be markedly affected by changes in posture (Fowler, 1949). Because the overall oxygenation and the carbon dioxide elimination from the blood are not disturbed by changes in posture, it has been assumed that a control mechanism exists by which the ventilation-perfusion ratio is adjusted. Thus it would appear that a change in the quantity of blood perfusing a lung segment may be of greater relative significance functionally than an unevenness in the distribution of the inspired gases (Dock, 1946; Lillenthal and Riley, 1954; Rahn, 1949; Roelsen, 1939; Svanberg, 1957). Nevertheless it is the latter which interests us in this investigation designed to elucidate the mechanisms by which atelectasis occurs during upper urinary tract surgery.

This problem was investigated along several lines. The compliance was examined in each individual lung with the patient first in the supine and then in the lateral nephrectomy position. Numerous radiographs were taken during inflation and deflation in both positions, and as these showed the lower lung to have a decreased volume, bronchograms were done to try and determine in which portion of the lung the decrease in volume was relatively greater. In most of the patients altered ventilation sounds were heard through a stethoscope fixed to the lateral side of the thorax.

COMPLIANCE STUDIES

Methods.

Compliance was studied in 10 female patients undergoing minor gynaecological procedures. None showed clinical evidence or had any history of cardiovascular or pulmonary disease. After a test dose of 5 mg d-tubocurarine chloride followed by a further 25 mg d-tubocurarine and 250 mg thiopentone, all were intubated with a No. 37 Carlens double lumen catheter using Jenkins's (1956) technique. In the catheter were placed two No. 3 Cobb's connectors, adapted to form a three-way and a four-way connection (figs. 1 and 2). The three-way Cobb's connector (B1) was connected to the side leading to the lung which was not being investigated. The other ends were connected to an aneroid manometer (C1) and a Boyle's mark II (D) circle absorber system. The four way Cobb's connector (B2) was connected to the other limb of the Carlens tube, a 6-litre Palmer spirometer (E), an aneroid manometer (C2) and the circle absorber (D).

The movements of the spirometer bell were recorded on a slowly moving kymograph (F). Clamping of the connecting tubing when necessary with an artery forceps was preferred to the use of taps or swivels as the connections were kept simple.

Compliance was tested at four different pressures by inflating the thorax via the Carlens tube by two anaesthetists. In the lung to be studied, this was done by exerting manual pressure on the spirometer bell until the aneroid manometer (C2) remained steady at the desired pressure and the graph tracing had reached its plateau. Simultaneously the opposite lung was inflated to the same pressure as shown on the manometer (C1) by compressing the rebreathing bag of the circle absorber system (D). In this way it was hoped that the mediastinum would not be displaced to

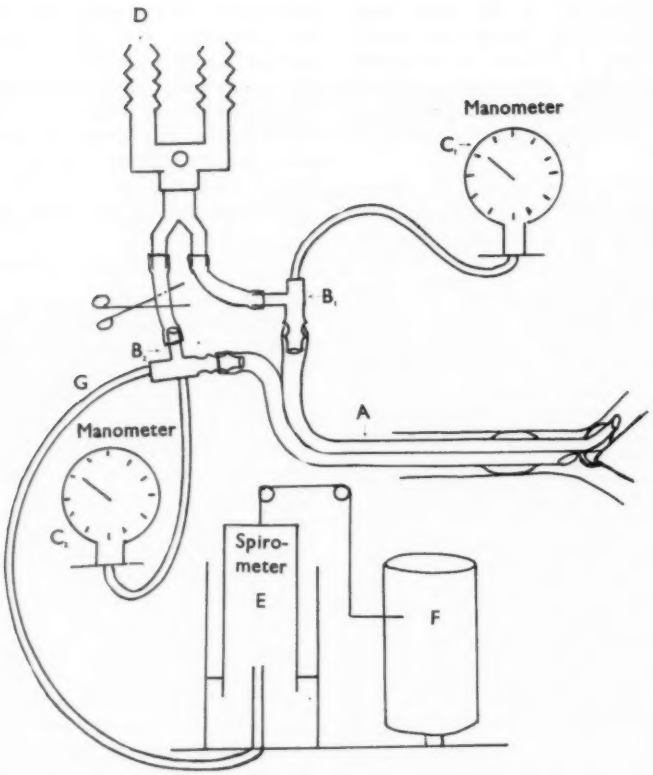

FIG. 1
Diagram illustrating apparatus.

either side. After readings had been taken in the supine position the patients were turned on to their right sides into the lateral nephrectomy position, care being taken to place the break of the table midway between the iliac crest and the lower ribs.

Readings were taken at 5, 10, 15 and 20 cm H_2O pressure. Immediately after the graph had reached its plateau, the pressure was released on the spirometer and the expiratory limb of the corrugated tubing was detached from the absorber (D). In this way both lungs deflated simultaneously. Immediately the tracing had returned to its base line the expiratory limb was reconnected and the pressures in both systems were simultaneously raised to the next level.

Readings were taken in numerical order (5, 10, 15, 20 cm H_2O) and four readings could be taken in about 70–80 seconds. The spirometer bell was filled with the same 2:1 nitrous oxide and oxygen mixture as the patient received between the measurements.

Before each set of tracings was made the tubing was released at G and connected to the manometer (C2) and four correction graphs were made at pressures 5, 10, 15 and 20 cm H_2O (fig. 3). This enabled a correction to be made for the water displacement which occurred in the spirometer due to the pressure changes. The recording pen was always zeroed on the same base line before the next pressure change was recorded. This was found necessary due to oxygen being

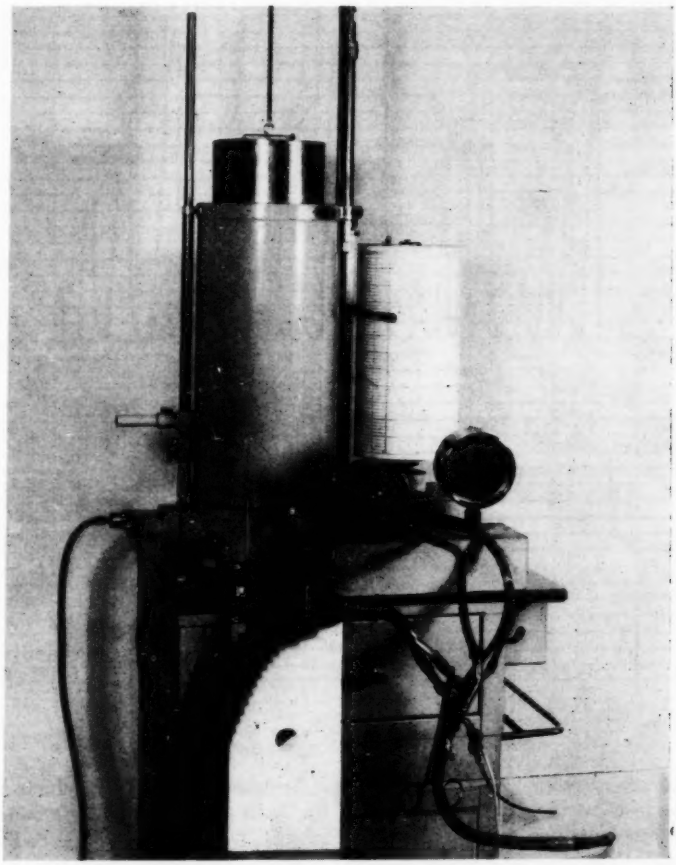

FIG. 2
Apparatus.

absorbed and some blood being displaced from the thorax at the higher pressures (Fenn et al., 1947). After every third set of recordings, the gas in the spirometer was flushed out and renewed.

Final volumes were measured after subtraction of the correction graph and not corrected for B.T.P.S. as the correction was so small as to be well within the limits of the experimental error. For the pressure-volume graphs of both lungs of the same patient, a set of four readings in one position were taken with the base line on the 4-litre mark of the graph paper. Cobb's connectors (B1 and B2) were then changed on the Carlens tube and the next readings were taken with the 2-litre mark of the graph paper as the base line. Thus all graphs pertaining to the same lung were in sequential order on the same base line opposite their own correction graphs.

In three patients "step" graphs were obtained below the base line (fig. 3) by clamping (G) and inflating both lungs simultaneously via the circle absorber system (D). As soon as a steady pressure

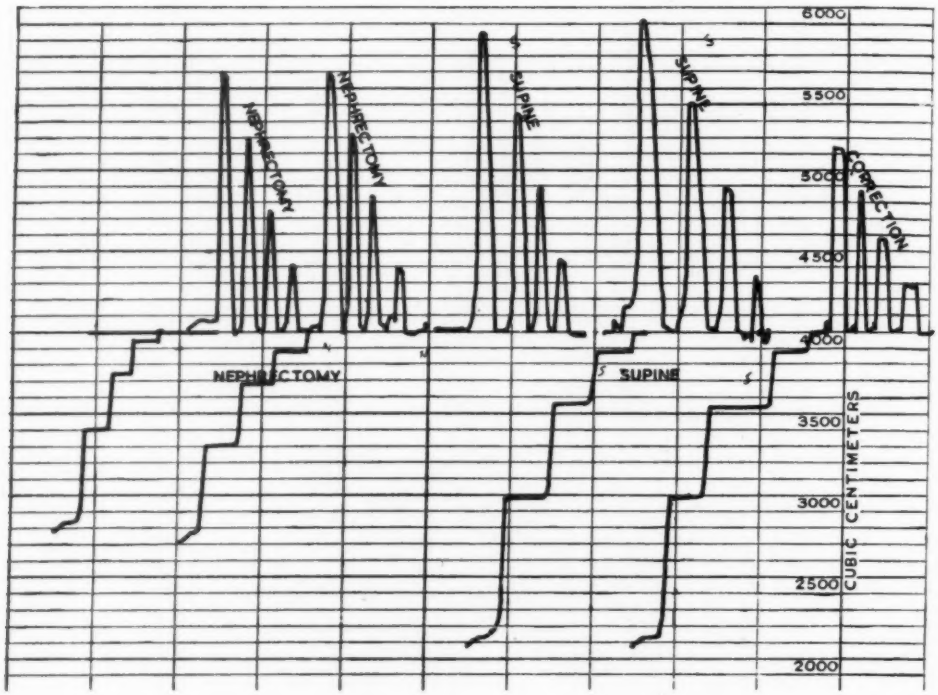

FIG. 3

was obtained the artery forceps was applied in such a manner as to allow the expired volume of the one lung to be measured on the spirometer.

The expiratory limb of the circle absorber was disconnected until the recording pen ceased to travel in a vertical direction in order to ensure prompt reversal to atmospheric pressure.

Results.

A wider variation in the volume changes was obtained with 5 cm H_2O pressure difference than in the volume changes resulting from higher pressure differences. This is due to the difficulty of keeping two aneroid manometers steady at such a low pressure, further complicated by the relatively large pressure changes due to cardiac action. In the pressure-volume graphs (figs 4, 5 and 6) it can be seen that the compliance of the lower lung is less in the nephrectomy position than in the supine position.

In figure 4 a pressure-volume graph is plotted for both the right and left lungs of the same patient when supine and in the nephrectomy position. Although the compliance of the upper lung, the left, diminishes in the nephrectomy position, it is not nearly as much reduced as in the lower lung, the right.

RADIOGRAPHIC INVESTIGATION

Methods.

Male subjects were selected for this part of the investigation as the female breast shadow tends to obscure the lower lung area. Three young patients for appendicectomy were studied. Anaesthesia was the same as previously mentioned. Radiographs were taken in the supine position and the patient was then turned to the right lateral position (i.e. the position for left nephrectomy). After 1 hour in this position the

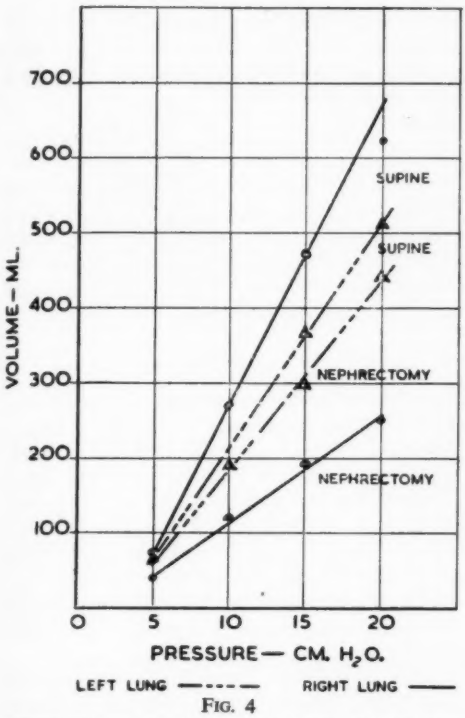

FIG. 4

Pressure-volume graph of both lungs of the same patient (C.F.P.) in the supine and nephrectomy position.

patient was then turned back to the supine position. On each occasion two radiographs were taken; the first during maximal lung inflation (fig. 7) and the second after expiration with the expiratory limb of the circle absorber open to the atmosphere (fig. 8). After the last radiograph had been taken in deflation in the nephrectomy position, the patient was rapidly turned on to his back and the next radiograph immediately taken. The lungs were then inflated and another radiograph taken.

Results.

The salient radiological features in the nephrectomy position are as follows. The mediastinum shifts to the right, more strikingly in the lower topographical lung area because here the heart encroaches relatively more upon the lung than in the upper thoracic region. The dome of the right (lower) hemidiaphragm is elevated and the left depressed (figs. 7 and 8). Due to the pressure of the operating table the lower intercostal spaces are narrower. The volume of the right hemithorax is smaller than that of the left. The left hemithorax is clearly the more translucent.

On maintained maximal inspiration very little movement of the right hemidiaphragm in a caudal direction could be discerned, compared to a much larger movement of the left hemidiaphragm. After the patient had been 1 hour in the nephrectomy position it was not possible to demonstrate radiologically any areas of collapse even after the ventilation sounds had changed from "vesicular" to "bronchial".

On regaining the supine position there was no demonstrable difference between the radiographs taken before and after the nephrectomy position which had been maintained for 1 hour.

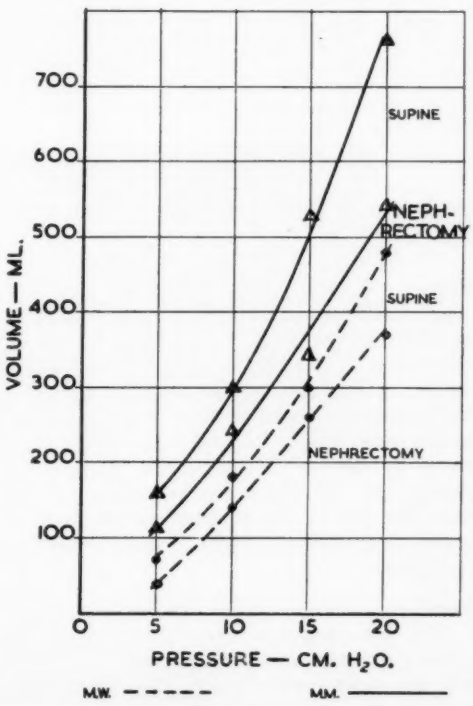

FIG. 5

Pressure-volume graph of right lungs of patients M. W. and M. M.

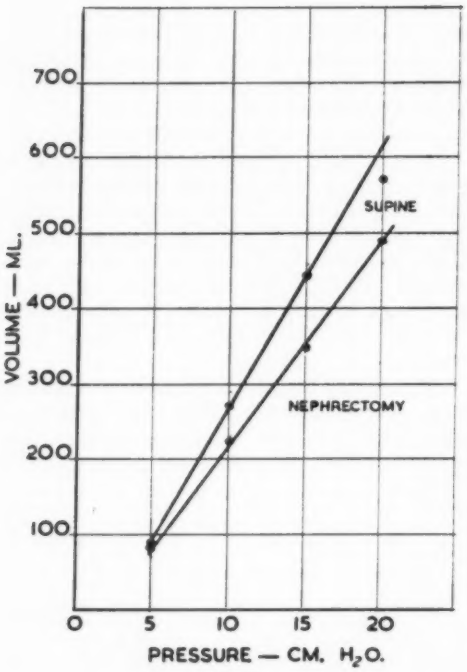

FIG. 6
Pressure-volume graph of right lung of patient O. K.

BRONCHOGRAPHIC INVESTIGATION

Method.

In 5 female patients anaesthesia was maintained with nitrous oxide-oxygen and halothane, and the right bronchial tree was filled with "Neo-hydriol" containing 8 g. of sulphanilimide per 25 ml. A first radiograph was taken with the patient lying on her side (fig. 9) followed immediately afterwards by another in the lateral nephrectomy position (fig. 10). Before the first radiograph was taken the patient was rendered apnoeic with 50 mg suxamethonium in order to avoid respiratory movements.

Results.

The bronchograms were performed in an attempt to demonstrate which portion of the lung was the more compressed by the nephrectomy position. Due probably to the supporting effect of the thick contrast medium, no collapse could be seen in the lower topographical area. However, by tracing the larger bronchi, the impression was gained that the middle and lower lobe bronchi were slightly more crowded than those of the upper lobe.

AUSCULTATION

A stethoscope was placed on the right side over the fifth intercostal space in the midaxillary line. With the patient in the nephrectomy position the heart sounds became much clearer and the characteristics of the ventilation sounds changed from "vesicular" to "bronchial".

DISCUSSION

From these experimental findings it can be concluded that the compliance of the lower lung is diminished during surgery in the lateral nephrectomy position. The compliance of the upper lung also diminishes slightly (fig. 4). This may be partly due to the weight of the upper shoulder. Probably more important is the position of the upper thoracic cage which now is relatively fixed in an inflated position, with the ribs spread and with the diaphragm and abdominal viscera more caudally displaced.

Thus, in artificial ventilation with the "educated hand" (which may be described as volume cycled and pressure limited), the tidal exchange provided through the cuffed endotracheal tube will be distributed according to the pressure-volume response of each individual volume component. In the lateral nephrectomy position it is clearly the upper lung which receives the larger moiety of the tidal volume. As increased ventilation cannot superoxygenate blood (Comroe, 1958), any areas which are underventilated will result in a diminished amount of oxygen in the arterial blood.

However, if the alveolar oxygen content is kept normal or even raised to about 30 per cent, as it may be when ventilating with nitrous oxide-oxygen mixtures of 2:1 litres respectively, local alveolar hypoxia is unlikely and the pulmonary vascular bed may even be maximally dilated (Stroud and Rahn, 1953).

Furthermore, because of the higher pressure in the pulmonary artery of the dependent lung, at least in theory, it can be expected that a larger moiety of the pulmonary blood-flow will go to

FIG. 8
Radiograph taken during deflation.
Patient in lateral nephrectomy position.

FIG. 7
Radiograph taken during inflation.
Patient in lateral nephrectomy position.

FIG. 9
Bronchogram of right lung. Patient in lateral position.

FIG. 10
Bronchogram of right lung. Patient in lateral nephrectomy position.

the lung with the least ventilation. This over-perfusion of an underventilated lung implies wasted ventilatory effort, or at least imperfect oxygenation of blood by a reduction in the effective blood-gas interface.

With spontaneous respiration a sizeable part of the lung is ventilated at a "slower" rate than the remainder (Blair and Hickam, 1955). Uniform underventilation of large portions of the lung, particularly a segment supplied by a single bronchus, together with restriction of lung movement, would presumably encourage atelectasis. Furthermore, the occurrence of well perfused but underventilated areas of the lung will increase the incidence of absorption atelectasis (Campbell et al., 1958).

By studying the bronchograms and the radiographs taken during inflation as well as deflation, it can be concluded that because of the external pressure upon the lower ribs by the operating table, and the very small range of movement of the diaphragm, due to the pressure of the abdominal viscera, even with a maintained maximal inflation of 20 cm H_2O pressure, expansion of the lower thorax is severely limited. Thus the lower topographical lung area (i.e. lower and middle lobe of the right lung) may well constitute a so-called slow space of ventilation.

Because of the decreased lung volume in this area collapse of the less rigid bronchioles might occur, as these might otherwise have been held open by the elastic tissue of the lung under stretch.

There may also be a tendency for the alveoli which are supplied by the shorter and broader bronchi to expand first during intermittent positive pressure ventilation (Butler and Smith, 1957), which may further compress alveoli situated more peripherally. In this way it is conceivable that the peripheral alveoli, already underventilated by the mechanical factors described, will progressively collapse as the anaesthetic proceeds. Another factor facilitating this is the presence of readily absorbable gases (nitrous oxide and oxygen) during anaesthesia as opposed to air (nitrogen and oxygen) normally present in the alveoli.

The administration of anticholinesterase drugs may be accompanied by bronchospasm and increased secretion into the respiratory tract. Furthermore any secretion in the bronchial tree will tend to gravitate to the main bronchus of the dependent lung, and from there, on changing to the supine position, to the lower lobes. Thus the nephrectomy position favours, by the mechanical factors involved, the collapse of peripheral alveoli. It may be impossible post-operatively, for the spontaneously breathing patient, to re-aerate these collapsed or partially collapsed alveoli.

Postoperative atelectasis does not usually occur as the result of only one predisposing factor, such as an unfavourable position during surgery. It is rather a combination of a number of factors precipitated by the anaesthetic and operative procedures, and abetted by postoperative factors. These adverse factors, such as increased bronchial secretion, retained as a result of respiratory movements limited by pain (Anscombe, 1957a, b), inability to cough "productively" (Greene and Berkowitz, 1953), general anaesthesia as such (Dripps and Deming, 1946), and hypoventilation, all act together.

Any patient with hypersecretion of mucus from large or small air passages, or interference with the normal bronchial ciliary action, should receive specific therapy for this pre-operatively. Random antibiotic therapy, commenced on the pre-operative night and followed up during the post-operative period, may prevent or mitigate the inflammatory sequelae of atelectasis. But on principle this is incorrect as, basically, atelectasis is a mechanical event, and therefore the best prophylaxis lies in the pre-operative clearance of the bronchi and the full re-aeration of the lungs postoperatively by means of intermittent positive pressure assistance. To allow the patient to recover consciousness in the lateral position while the wound dressings are being applied must be avoided, because the lower lung is not then fully aerated. It is advisable to persevere with controlled ventilation postoperatively with the patient in the *supine* position for at least 10 to 15 minutes, so that the atelectatic area may be fully re-aerated.

SUMMARY

From findings gathered by means of studies of compliance bronchograms and radiographs of the lower lung in the lateral nephrectomy position,

it is concluded that the lower lung cannot be adequately ventilated during controlled respiration. Absorption atelectasis appears to develop which might persist after the patient regains the supine position. It is therefore necessary to continue with controlled respiration in the supine position to re-aerate these collapsed areas of lung.

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ASSOCIATION OF ANAESTHETISTS OF GREAT BRITAIN AND IRELAND

Essay Prize

The Council of the Association of Anaesthetists of Great Britain and Ireland is at present especially interested in matters which may improve the efficacy and safety of dental anaesthesia. It has therefore been resolved to offer a prize of 200 guineas for the best essay based upon new and original work related to the subject of general anaesthesia for dental surgery. The Council would especially welcome essays dealing with the morbidity and the safe practice of general anaesthesia in the dental chair.

Essays should be submitted to the Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 47 Lincoln's Inn Fields, London, W.C.2, on or before March 1, 1961. Intending candidates should apply to the Honorary Secretary at the above address for the regulations governing the submission of essays.

Brit. J. Anaesth. (1959), **31**, 484

BLOOD LOSS DURING PROSTATECTOMY

BY

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PROSTATECTOMY is an operation in which all surgeons, however skilled, sometimes have difficulty in controlling haemorrhage. As the operation is usually done in elderly men who cannot withstand severe haemorrhage, it is important to estimate the blood loss and to replace it; alternatively the anaesthetist can take steps to diminish the bleeding by lowering the blood pressure. Figures for the measurement of blood loss during this operation are not easily found in the literature. Lenahan et al. (1948) measured blood loss by weighing; in ten prostatectomies they found that this averaged 551 ml. Goodyear and Beard (1949) measured blood loss during and after prostatectomy by a colorimetric method; in twelve cases it averaged 368 ml. Jacobs (1957) claimed for retropubic prostatectomy an average blood loss of 200 ml; generally the volume of blood loss was between 40 and 400 ml and exceptionally was as high as 600 ml. These were the amounts collected by suction. Cox (1953, 1957) regarded 550 ml as an average loss of blood for prostatectomy and claimed that this can be reduced to 30 ml by using a hypotensive agent. Walters (1957) and Shepherd (1957) also advocated hypotension to diminish bleeding during this operation. The three latter authors do not state upon how many measurements their conclusions were based.

The purpose of this paper is to report the results of two series of blood loss measurements during operation in one hundred unselected patients undergoing prostatectomy. The first series consisted of fifty patients constituting the control group and the second consisted of fifty patients whose systolic blood pressures were lowered, or fell spontaneously to below 100 mm Hg for the whole operation. All these patients were anaesthetized by the author. No attempt is made here to discuss the hazards of the technique.

The method used was to measure the amount of blood aspirated into the sucker bottle, from the completion of the abdominal incision to the time of closure of the prostatic capsule. The use of swabs for mopping was discouraged and care was taken not to aspirate water found in the bladder at the beginning, or the washings at the end of the operation. This method is somewhat lacking in finesse, but it is an actual measurement of a volume of blood lost during a routine operation performed by experienced urologists. In the absence of any comparable series employing a more accurate method, the results are worth recording. It must be clearly understood that the measurements reported are in all cases less than the actual blood loss; but the figures probably bear some relation to the total loss, as more blood escapes on swabs and towels in the severe haemorrhages than does when the field is practically dry.

The anaesthetic agents and techniques used were the same in all the patients in both series. Induction with thiopentone 500 mg was followed by suxamethonium 50 mg and by intubation with a large cuffed tube. Anaesthesia was maintained with nitrous oxide and oxygen. d-Tubocurarine chloride 15 mg was employed for relaxation and artificial ventilation was maintained by hand or pump. In forty-eight cases in the second series hypotension was deliberately induced by the administration of hexamethonium bromide intravenously. The dose of hexamethonium in milligrams was calculated by subtracting the age of the patient (in years) from one hundred. In the remaining two patients of this series the systolic blood pressure fell "spontaneously" to below 100 mm Hg. The operating table was tilted 10 degrees head down and the blood pressure was taken at 5-minute intervals. The systolic pressure usually fell to between 60 and 75 mm Hg. The anaesthesia for the whole operation, including the pre-

liminary cystoscopy, lasted less than 1 hour except when haemorrhage was severe. When the field of operation was practically dry, the procedure was frequently completed in 30 to 40 minutes. In the second series the systolic blood pressure had usually risen to 80 mm Hg before the end. When this figure was not reached, methylamphetamine 2 mg was administered once or twice intravenously. The patient was then returned to the ward and the foot of the bed was raised until the pulse was strong at the wrist and the patient had regained consciousness.

RESULTS

In the fifty control cases the average measured blood loss was 346 ml (12.3 fl.oz: S.D. = 6.37). In the hypotension series the average loss was 94 ml (3.3 fl.oz: S.D. = 2.15). The difference between these means is highly significant ($P<0.0001$). Figure 1, constructed from table I, illustrates the findings graphically.

DISCUSSION

The blood loss in the hypotensive series was significantly less than that in the control series. Several points of interest arise:

Firstly, the measurements of blood loss in the control series ranged from 28 ml (1 fl.oz) to 710 ml (25 fl.oz) and are comparable with Jacobs' figures of 40 to 600 ml. This wide range may explain the different results claimed by those who have not actually attempted to measure blood loss during this operation.

Secondly, although the blood pressure frequently fell as a result of the anaesthetic drugs administered to these patients, this did not have a striking effect on the blood loss unless the systolic pressure fell below 100 mm Hg and remained there for the duration of the operation. Two such cases occurred in the second series and the fall of blood pressure is described as "spontaneous". In another two patients the administration of the dose of hexamethonium bromide described failed to lower the systolic blood pressure below 100 mm Hg. There was no reduction in bleeding and these cases have been included in the control series. These were regarded as failures of the method.

Thirdly, in the control series, there appeared to be no means of predicting whether a patient was likely to bleed little or much. In this context

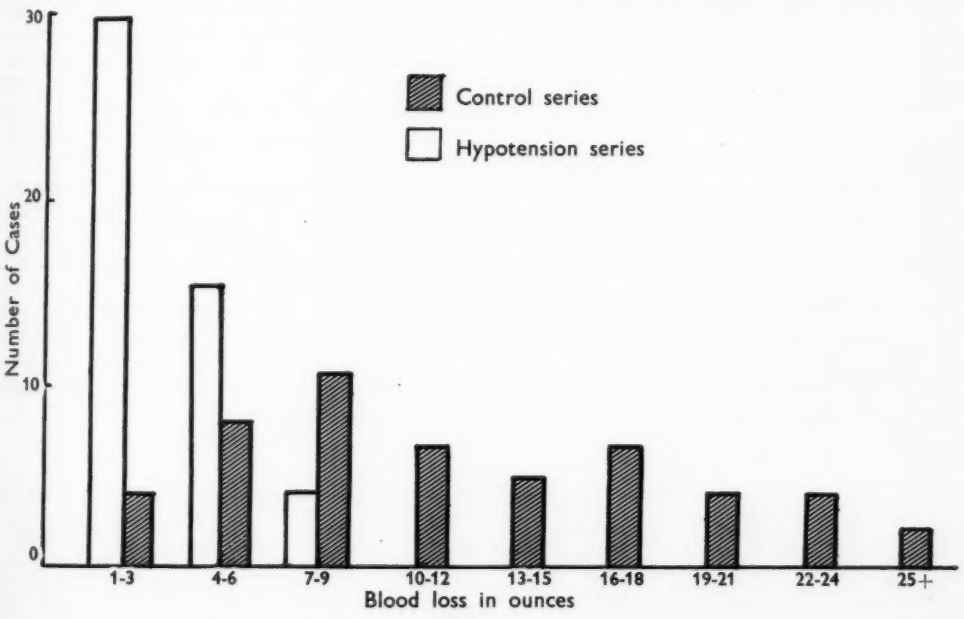

FIG. 1

TABLE I

Number of controls	3	7	11	7	5	7	4	4	2
Number of hypotensive cases	30	16	4	0	0	0	0	0	0
Blood loss in oz.	1–3	4–6	7–9	10–12	13–15	16–18	19–21	22–24	25+

it is interesting to note that no correlation could be demonstrated between the age of the patient and the blood lost at operation, the age of the patient and the length of stay in the hospital after operation, or the blood lost during operation and the length of stay in hospital.

With regard to blood transfusion, the following quotations are typical examples from the literature and of common practice in open prostatectomy. Boyd (1956) says "bleeding at operation is usually sufficient to warrant a pint of blood being given", and McEachern (1958) " . . . inspection of the sucker bottle and the swabs at the end of each operation, will justify the routine administration of 600 c.c. of blood in all cases". The criterion used in the present two series was to administer blood if there was 10 ounces (280 ml) or more in the sucker bottle. Thirty of the fifty controls lost this quantity of blood and these patients were transfused. In the hypotensive series no patient lost more than 9 ounces of blood and no blood transfusions were needed. In both series plasma or dextran was given when the blood loss was more than 5 ml but less than 10 ml.

In an attempt to demonstrate that the patients in the two series were comparable clinical risks, I have reproduced three sets of figures. These show the age of the patient at the time of operation, the length of stay in hospital after operation and the mortality (see table II). The figures favour the hypotensive series, but the differences are not significant. It is interesting to note that the figure quoted by McEachern (1958) for the average length of stay in hospital—27 days in 220 cases—is almost identical with the average for the patient in the controls group in this series. The average age of a group of patients does not help to assess the risks involved in an operation. I have therefore followed Jacobs (1951) in quoting the number of patients over 75 years and over 80 years of age. In the present series of one hundred patients, 27 were 75 years of age or over and twelve of these were 80 years of age or more. This compares with the corresponding findings of Jacobs (16 per cent and 2 per cent).

The mortality in this series is higher than that usually reported in the literature. The reason appears to be that this urological unit serves a large chronic geriatric population. However, none of the deaths was regarded as attributable to the anaesthetic. Table III shows the causes of the deaths. One case needs special mention: a man of 78 years died of a coronary thrombosis 10 days after operation, during which his blood pressure was lowered with hexamethonium bromide. This patient made a satisfactory immediate recovery from his operation and was ambulant when on the tenth day he suddenly developed the symptoms of coronary occlusion and died. The post-mortem findings were " . . . coronary occlusion (gross narrowing of all coronary arteries by calcified atheroma) and myocardial fibrosis". There was no evidence of recent myocardial damage such as might have been expected if the hypotension induced at operation had been responsible. The fact that this man survived his operation possibly supports the argument that the low blood pressure in the coronary vessels at the time of operation was offset by the diminished oxygen requirements of the heart accompanying a low pressure and a diminished cardiac output.

TABLE II

	Days in hospital after op.	Average age (years)	75–79	80 and over	Deaths	Average age at death
Controls	26.8	68.5	10	7	7	74.4
"Hypotension"	22.6	69.9	5	5	4	79.0
Both series	24.7	69.2	15	12	11	77.0

TABLE III

	Age	Days after operation	Cause of death
Controls	83	71	Perforated duodenal ulcer with peritonitis
	72	3	Massive haematemesis
	80	38	Myocardial degeneration, senility, attempted suicide
	70	10	Massive pulmonary embolus
	81	5	ditto
	63	15	ditto
	72	33	Ischaemic heart failure and pyelonephritis
"Hypotension"	78	10	Coronary thrombosis (see text)
	73	8	Bronchopneumonia
	87	3	Bilateral pyelonephritis and bronchopneumonia
	78	22	Suppurative pyelonephritis

CONCLUSIONS

Lowering the systolic blood pressure of a patient reduces the blood lost during prostatectomy. This assists the surgeon, as it removes the difficulty of the field being obscured by haemorrhage. The patient's own blood is conserved. In the present investigation the induction of hypotension did not carry a higher morbidity or mortality than the control series.

SUMMARY

The blood loss was measured during prostatectomy in one hundred unselected patients consisting of a control series of fifty patients and fifty others in whom the blood pressure was lowered. The average loss in the control series was 346 ml (12.2 fl.oz) and in the hypotension series 94 ml (3.3 fl.oz).

Blood transfusions were given to thirty of the fifty patients in the control series but to none of the patients whose blood pressure was deliberately lowered.

There was no significant difference between the two series with regard to age, morbidity or mortality.

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CARDIAC IRREGULARITIES IN CATS UNDER HALOTHANE ANAESTHESIA

BY

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EXPERIMENTS carried out during the past eighteen months on the effects of halothane on the cardiovascular system of cats may throw further light on some aspects of the work of Raventós and Dee (1959) on cats anaesthetized with azeotropic mixtures of halothane and ether. This brief summary of the relevant results has, therefore, been prepared. It is hoped that a more detailed account of the investigation will be published in due course.

METHODS

All the experiments were performed on healthy young adult cats. The anaesthetic agents were delivered from a standard Boyle's anaesthetic apparatus, a Fluotec or an Oxford Mark I vaporizer being incorporated as necessary. Halothane or ether was vaporized using a mixture of equal parts of nitrous oxide and oxygen at a total flow rate of 6 litres per minute. Cyclopropane was added to the nitrous oxide/oxygen mixture to give the required concentration while the total gas flow rate was maintained at 6 litres per minute.

Anaesthesia was induced by placing the cat in a large glass tank into which the anaesthetic agents were introduced through narrow bore tubing. When third plane anaesthesia had been reached, the cat was removed from the tank and placed on its back on the operating table. Anaesthesia was maintained using either (i) a cat face mask and Magill attachment, or (ii) a No. 2 or No. 3 plain Magill endotracheal tube and T-piece, endotracheal intubation being performed under direct vision after the intravenous administration of 3 mg of suxamethonium chloride.

Standard limb lead electrocardiograms from subcutaneous needle electrodes and the blood pressure from a cannulated femoral artery were recorded simultaneously on a direct writing multichannel recorder (Cambridge Instrument Co. Ltd.).

RESULTS

Sixteen cats were anaesthetized with halothane and anaesthesia was maintained with a concentration of 1 per cent of this agent. Fourteen of these animals developed a cardiac irregularity within the first hour of anaesthesia. The onset of this irregularity was delayed and it was never seen until the animal had been anaesthetized for at least 15 minutes. The character of the irregularity was constant (fig. 1). A sudden increase in the concentration of the halothane to 2 per cent was followed by an immediate return to a normal electrocardiographic pattern, but the irregularities reappeared within a few minutes. Returning the concentration of halothane to 1 per cent then had no effect on the electrocardiogram but increasing the strength to 3 per cent again resulted in an immediate, but temporary, return to normal rhythm.

The irregularities were also abolished, but with a delay of a few seconds, by positive pressure hyperventilation. This effect was not obtained when 5 per cent carbon dioxide was added to the gases used for hyperventilation. Estimation of the carbon dioxide content of serial arterial blood samples taken during these manoeuvres showed that the disappearance of the irregularities coincided with a fall in the carbon dioxide content of the blood.

For control purposes three cats were anaesthetized with ether and anaesthesia maintained with

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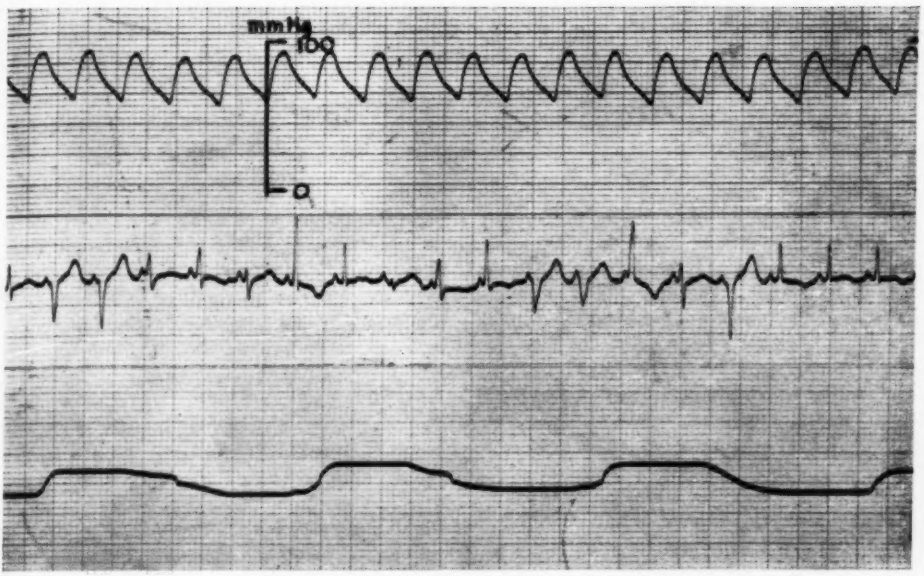

FIG. 1

Cat: 1 per cent halothane, nitrous oxide and oxygen.
Upper tracing: Arterial blood pressure.
Middle tracing: Lead II e.c.g.
Lower tracing: Respiratory recording; upward deflection indicates inspiration.

10 per cent ether vapour for the first hour and 20 per cent ether vapour for the second hour. No cardiac irregularities were observed in these three cats. A further two cats were anaesthetized with cyclopropane and anaesthesia maintained with 12.5 per cent cyclopropane. One of these cats exhibited a cardiac irregularity similar to that seen under halothane anaesthesia. In this animal positive pressure hyperventilation abolished the irregularity.

DISCUSSION

It is clear from these results that cardiac irregularities occur in cats anaesthetized with 1 to 3 per cent of halothane vapour and are not as uncommon as is suggested by Raventós and Dee (1959). The tracings of the irregularity have been examined in some detail and study of longer lengths than that shown in figure 1 suggests that they show either interference dissociation or multifocal extrasystoles. The abolition of the irregularities by measures designed to reduce the carbon dioxide content of the blood indicates that, as suggested by Johnstone (1956), hypercapnia predisposes to their onset. This fact, coupled with the failure of section of the vagus nerves to abolish the established arrhythmia, favours the latter alternative. It is hoped that further investigations will clarify this point.

A most important feature of the results is the delay before the onset of the irregularity and this might explain why the irregularities noted by Raventós and Dee in one cat appeared to start only after the inhalation of the azeotropic mixture.

ACKNOWLEDGMENTS

We wish to thank Mr. D. E. Stevenson, B.Sc., B.V.Sc., M.R.C.V.S., for performing the estimations of carbon dioxide in the arterial blood samples and Imperial Chemical Industries (Pharmaceuticals) Ltd. for generous supplies of Fluothane.

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HALOTHANE AND THE BLOOD SUGAR

BY

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IT has been known since the beginning of the century that diethyl ether anaesthesia produces an increase in the blood sugar content (Underhill, 1906). Most other volatile anaesthetics give rise to a similar response. As each new agent has become available it has been investigated with this in view and it seemed desirable to carry out a study of this kind for halothane. For apart from a short note on the matter in a more general paper (Stephen et al., 1957) no detailed investigation had until recently been made.

METHODS

Twenty patients in all were studied. Ten of them underwent general surgical operations. In them an initial specimen of venous blood was taken either immediately before induction or immediately before turning on the halothane. Subsequent specimens were withdrawn at intervals during anaesthesia. These patients were premedicated with morphine 10 mg and atropine 0.6 mg, or papaveretum 20 mg and hyoscine 0.4 mg. Anaesthesia was induced with a sleep dose of thiopentone. Suxamethonium in a dose of 40–50 mg was given and an endotracheal tube passed while the patient was paralyzed. Ten neurosurgical patients were anaesthetized by a similar technique, described in detail elsewhere (Hunter, 1954, 1958). Specimens were withdrawn immediately before turning on halothane and at intervals of approximately half an hour during the subsequent administration of the drug. The halothane was administered either from a Boyle's bottle calibrated at a temperature of 70°F or with the aid of a Fluotec vaporizer. By either method the percentage of halothane varied within the limits of 0.7 and 2 per cent. No attempt was made to keep the concentration at one single level. It was modified to meet the needs of the individual patient and the stage of the operation in progress. Blood sugar determinations were carried out in duplicate by the method of Maclean (1919), which has in this laboratory a standard error of ± 5 per cent.

RESULTS

The blood sugar changes in the patients are shown in figures 1 and 2. It will be apparent that in the general surgical cases the results were somewhat irregular. In the neurosurgical cases, however, the blood sugar level remained constant over long periods of halothane administration. In neither group was there any great deviation from normal levels, nor was there any suggestion of the constantly climbing blood sugar content which regularly appears during other forms of inhalation anaesthesia with volatile agents.

DISCUSSION

During the administration of diethyl ether it has been noted that the blood sugar content doubles itself in half an hour, and provided that there is enough glycogen in the liver it will increase by the same amount in the second hour (Mackay, 1928; Cantarrow and Gehret, 1931). A similar state of affairs was shown by the author to hold for methyl n-propyl ether (Hunter, 1950) and hyperglycaemia has also been shown to occur in the patient anaesthetized with cyclopropane (Neff and Stiles, 1936). The results of this investigation indicate that the blood sugar changes produced by halothane in concentrations of up to 2 per cent are negligible by comparison.

It is almost universally accepted that the rise in blood sugar during ether anaesthesia is due to adrenaline release produced by the action of the drug on the centres of the brain which govern autonomic activity (Banerji and Reid, 1933; Brewster et al., 1952; Bunker et al., 1952). The fact that halothane does not cause a rise in

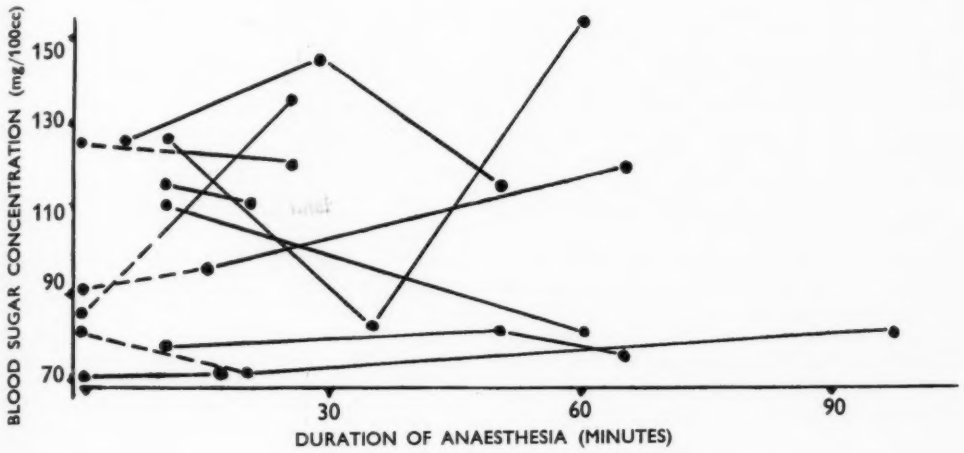

FIG. 1

The blood sugar changes in general surgical patients anaesthetized with nitrous oxide, oxygen and halothane. (The lines are broken to indicate a period of anaesthesia in which no halothane was given.)

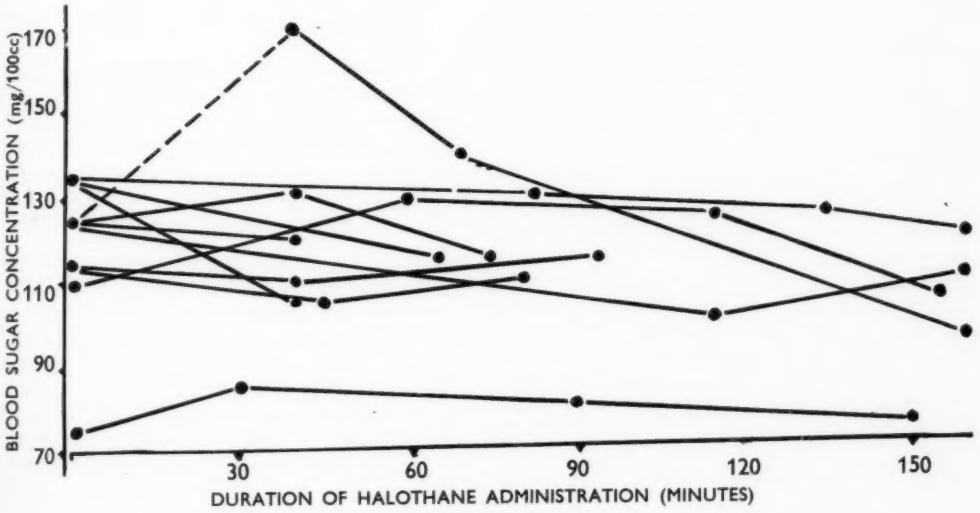

FIG. 2

The blood sugar changes in neurosurgical patients anaesthetized with nitrous oxide, oxygen and halothane. (Zero time indicates the moment of adding a halothane supplement to the anaesthetic mixture. It was usually some 20 to 50 minutes after induction. The broken line indicates a rise in blood sugar produced by injecting local anaesthetic solution containing adrenaline.)

the blood sugar is almost certainly confirmatory evidence of its power of depressing the activity of the sympatho-adrenal system. This fact is, of course, manifested more obviously in clinical anaesthesia by hypotension and peripheral vasodilatation, but it would seem that the basic mechanism in both hypotension and relative absence of blood sugar change is the same.

Since this work was completed Keating (1959) has published evidence that the blood sugar content rises in Jamaicans under the influence of halothane. It is, however, to be noted that the rise in his cases, though undoubtedly significant, was not commensurate with that occurring with diethyl ether anaesthesia, nor are the final blood sugar levels greatly different from those reported in the present series.

ACKNOWLEDGMENTS

The blood sugar estimations were carried out by the staff of the Biochemical Department of the Clinical Laboratory of Manchester Royal Infirmary. The author is indebted to Mr. H. Varley, the senior biochemist, for his kind co-operation in this work.

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INDUCTION OF ANAESTHESIA IN THE FOOT-DOWN POSITION FOR PATIENTS WITH A FULL STOMACH

BY

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THE inhalation of gastric contents is probably the most common cause of death during anaesthesia, With the introduction of the intravenous barbiturates and the relaxants, the problem has become more acute since, with these agents, gastric contents may reach the larynx when the protective reflexes are in abeyance.

We have confirmed the experience of Weiss (1950) and Culver, Makel and Beecher (1951) that, in some 25 per cent of patients, gastric contents may reach the pharynx during the course of an anaesthetic. However, the danger of aspiration under these circumstances may be avoided by intubation with a cuffed endotracheal tube and the major problem with which this paper is concerned is aspiration during induction.

METHODS OF PREVENTION OF ASPIRATION

Avoidance of general anaesthesia.

This has been our method of choice when it is applicable. We have made extensive use of regional blocks in the case of trauma to limbs. Pudendal block has greatly reduced the number of general anaesthetics given for forceps delivery.

Emptying the stomach pre-operatively.

This would appear to be both the logical and the safest method of preventing the aspiration of stomach contents. Unfortunately there are certain disadvantages and it may not be possible to be certain that the stomach is in fact satisfactorily emptied. Edwards et al. (1956) refer to nineteen cases in which attempts to empty the stomach were followed by fatal aspiration during induction. Not only are there technical difficulties in emptying the stomach, but it is possible for the stomach to refill from the duodenum before induction is carried out.

Under certain circumstances, such as foetal distress, there may not be time to empty the stomach. Also, with some hesitation, we would mention as a disadvantage, the passage of a wide-bore tube on a severely ill patient. If it is life-saving then clearly it is essential, but those who are conversant with the procedure will be prompted to enquire whether any other method will confer an equal degree of safety.

Our major objection to relying upon the pre-operative emptying of the stomach is the very large number of patients who are at risk. In this respect the experience of individuals varies according to the types of cases they are called upon to anaesthetize. But, to the resident anaesthetist at a general hospital with a large emergency intake it quickly becomes apparent that the problem of aspiration is not confined to "emergency abdomens" and obstetrics. Safety can only be achieved by the routine emptying of stomachs on a large scale.

Preservation of the laryngeal reflex during induction and intubation.

One of the principal advantages of induction of anaesthesia with inhalational agents, such as ether, is that, should vomiting occur, the laryngeal reflex will normally be present and there should be no aspiration. The airway is thus protected primarily by the patient rather than the anaesthetist and this is advantageous should the latter be inexperienced. Nevertheless, in a seriously ill patient the laryngeal reflexes are less active than normal and vomiting may well be dangerous during an induction with inhalational agents.

Blocking of the cardia or oesophagus.

From time to time, techniques are described in which balloons, packs or tubes are passed into the oesophagus with a view to preventing or diverting the reflux of gastric contents. We have not used these techniques since we thought that too much depended upon the accurate positioning of such a blocker. No report has been made of the safety of these techniques in a large series.

Induction in the Trendelenburg or lateral position.

The suggestion is often made that induction should be carried out in a position which will cause regurgitated gastric contents to drain away from the pharynx before aspiration can occur. So far as we are aware, no-one has shown this to be unsafe but, nevertheless, it would appear to be preferable to employ a technique which prevents regurgitation rather than one which merely renders it inoccuous.

Intubation or tracheostomy before the induction of anaesthesia.

If there is no direct access to the larynx and if there is any possibility of vomiting or regurgitation then preliminary intubation is essential. We have carried out this procedure in cases of severe facial injuries.

Rapid induction and paralysis in the foot-down position.

Morton and Wylie (1951) suggested that a foot-down tilt of at least 20° might be effective in preventing regurgitation following the exhibition of thiopentone and a full dose of a muscle relaxant. They stressed the possible undesirable circulatory effects of the combination of position and thiopentone and considered it a technique suitable only for fit patients and experienced anaesthetists. Scurr (1958) goes further and suggests that the upright position should be adopted.

Although the technique has probably been used widely, only the recent work of Hodges et al. (1959) has testified to its safety. Many are reluctant to adopt a technique which is not supported by a considerable body of evidence and it is for that reason that this paper is presented.

THE ACTION OF THE CARDIA

It is now generally agreed that the prevention of regurgitation is not due to any pinchcock action of the crura (Braasch and Ellis, 1956) and that the cardiac "sphincter" is of little if any importance. Thus, O'Mullane (1954) showed that the cardia resisted reflux if the patient was curarized, if the sympathetic ganglia were paralyzed and finally if the region of the cardia was painted with amethocaine. Perhaps the most convincing evidence against these mechanisms is the finding of Marchand (1954) that the cardia is competent in the cadaver.

It is now thought by many that the essential mechanism is that of a valve (O'Mullane, 1954; Dornhorst, Harrison and Pierce, 1954). It is, however, difficult to reconcile this mechanical theory with the dramatic regurgitation of gastric contents which may follow the induction of anaesthesia with intravenous agents. There are two possible explanations of this discrepancy.

Dornhorst and his co-workers (1954) showed that during Muller's manoeuvre a pressure differential of 80 mm Hg might exist between stomach and oesophagus. It is conceivable that during induction with thiopentone and a relaxant there might be a short period of time when the tongue had fallen back to obstruct the airway although respiration was still present. Under these conditions it is possible that a pressure differential would develop across the cardia which would be sufficient to force the "valve".

The second possible explanation is that patients who regurgitate during induction of anaesthesia have already an incompetent cardia beforehand (Dinnick, 1957). These patients would normally rely upon the striped muscle of the upper part of the oesophagus for protection of the larynx and this protection would be abolished by the use of a relaxant (Sinclair, 1959). Striking confirmation of this theory has been obtained by Dinnick (personal communication) who followed up five patients who regurgitated during induction and in each case found an incompetent cardia at postoperative barium meal. Further support is lent to this theory by the fact that many patients do not regurgitate during induction but are subsequently found to have a full stomach.

Of the greatest interest were O'Mullane's observations of the intragastric pressure. He found the normal pressure to be of the order of 5 cm water and even with distension of the abdomen it did not rise above 18 cm water unless there was contraction of the abdominal wall. The intragastric pressure was found to fall when patients were tilted foot-down.

It would, therefore, appear that induction with thiopentone and a relaxant would be safe provided two conditions were fulfilled:

(1) That the abdominal muscles did not contract.

(2) That the larynx was maintained at a height (in centimetres) above the cardia *greater* than the intragastric pressure (in centimetres of water).

If anaesthesia is rapidly induced with thiopentone and a suitable relaxant, contraction of the abdominal muscles at any stage is very unusual. The second requirement may be met by the appropriate foot-down tilt of the table.

Degrees of tilt	Height of larynx above cardia (cm)
20	12.5
30	16
40	19

(These figures are based on a larynx-cardia distance of 25 cm and a 10° inclination of this line to the vertical axis of the body. They are not applicable to children.)

TECHNIQUE

No attempt need be made to empty the stomach unless there is distension, in which case the intragastric pressure should be reduced by aspiration. A Ryle's tube is usually sufficient for this purpose.

Anaesthesia is induced on the table in the operating theatre. The table should be equipped to prevent the patient sliding off it at steep angles of tilt.

The anaesthetic equipment and sucker should be carefully checked before induction as the technique allows no time for the replacement of missing or defective apparatus. We believe that a sterile bronchoscope should be available in every theatre which handles emergency surgery.

The body of the patient should be placed in a steep foot-down tilt in either of the positions shown in the figure. Additional height may be obtained by having two pillows under the head and shoulders.

An adequate dose of thiopentone (150–300 mg) is injected. This is followed (or accompanied) by gallamine (80–160 mg). Gallamine is preferred to tubocurarine because of its more rapid action and to suxamethonium because it is feared that the depolarization of the abdominal muscles might raise the intragastric pressure. We are not convinced that, in large doses, the action of gallamine is appreciably slower in onset than that of suxamethonium. During or before induction 100 per cent oxygen is administered with a face mask.

After injecting thiopentone and gallamine, the anaesthetist takes station at the head of the patient—standing on a stool if necessary. As consciousness is lost the lungs are inflated with oxygen and as relaxation becomes complete the endotracheal tube is introduced. The cuff is then inflated, the table levelled and the patient ventilated with a nitrous oxide-oxygen mixture.

During the course of the operation, the stomach may be emptied through a wide-bore tube which is passed at leisure.

With the technique as described, it is unusual for the patient to be exposed to the combination

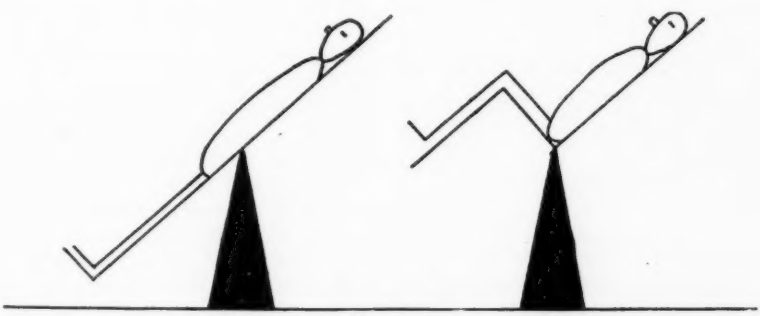

FIG. 1

Alternative positions in which the patient is tilted to an angle of 40° to the horizontal, thus raising the larynx approximately 20 cm above the level of the cardia.

of thiopentone anaesthesia and the foot-down tilt for more than 60 seconds. It is unlikely that hypotension during this period would be harmful.

A serious situation develops if the anaesthetist is unable to introduce an endotracheal tube into a paralyzed patient with a full stomach in the foot-down position. In the last five years we have encountered only one patient whom we failed to intubate. She had multiple deformities due to congenital syphilis and would not have been considered a suitable candidate for the technique here described.

CONTRA-INDICATIONS

There appear to us to be only two contra-indications to the use of this method, provided always that the anaesthetist is sufficiently competent to undertake anaesthesia at all for these cases. These are:

(1) Absence of a suitable operating table and other equipment.

(2) Deformity or injury which might render intubation difficult.

It is worthy of note that the "dystrophic" type of patient, so frequently seen at Caesarean section, may be difficult to intubate on account of the short neck associated with the condition.

RESULTS

The technique as described has been used by us for five years. Table I indicates the groups of patients so anaesthetized.

TABLE I

Caesarean section (including emergency) ...	480
Intestinal obstruction	46
Perforated peptic ulcer	19
Emergency gastrectomy for haemorrhage ...	31
Emergency laparotomy for conditions not found to be amenable to surgical treatment	12
Trauma to abdomen and face	8
Femoral embolectomy	1
Twisted ovarian cyst	3
Drainage of intra-abdominal sepsis	5
Ectopic gestation	1
Total	606

All cases of Caesarean section are included in one group as the risk of aspiration is not precluded by the customary period of starvation before elective operation. No cases of forceps delivery are included as these patients were not delivered on operating tables and tilting was not practicable.

Among the patients listed in table I there was only one instance of regurgitation. This occurred in a patient in whom the dose of relaxant had been badly underestimated. As the tube entered the larynx an explosive cough forced a large quantity of liquid stomach contents into the pharynx. No aspiration occurred. Lest it should be imagined that the authors are less than normally accident prone we append (table II) a list of the patients anaesthetized by us who have regurgitated and inhaled gastric contents. In these cases anaesthesia was induced with thiopentone and relaxants in the supine position, since the risk of aspiration was not appreciated.

TABLE II

1952	Stab wound of liver (J.F.N.)
1954	Laparotomy on a diabetic patient (oral glucose) (J.F.N.)
1954	Caesarean section (J.F.N.)
1955	Severe burns (J.F.N.)
1955	Cystoscopy for clot retention (R.G.S.)
1955	Emergency prostatectomy (R.G.S.)

There was no clinical evidence that any patient suffered from circulatory disturbance although it was not practicable to measure the blood pressure during the period of induction. In two cases (J.F.N.) it was deemed prudent to omit the thiopentone and induce anaesthesia with cyclopropane, but it is appreciated that the use of an inhalational agent increases the hazard of vomiting.

There was no instance of failure to intubate in this series. Some difficulty was experienced with one patient who was of a pronounced "dystrophic" type. The endotracheal tube was usually passed at the first attempt.

In the Caesarean sections the time from induction of anaesthesia to delivery varied from 15 to 25 minutes. There was no evidence of foetal depression and in this respect we are in agreement with the results of Hodges et al. (1959). It was not to be expected that the dose of thiopentone used would result in a high foetal blood level after 15 minutes (Crawford, 1956). It was, however, of interest that in no case was there any suggestion of foetal myoneural block, although at the time of delivery many of the

mothers were still apnoeic. It is not easy to reconcile this finding with the view that gallamine crosses the placental barrier (Crawford, 1956).

No patient raised any objection to being anaesthetized in the operating theatre rather than in the anaesthetic room. Most patients were more concerned with their condition than with their environment and their attitude differed from that of patients admitted for planned surgery.

COMMENTS

Our results suggest that rapid induction of anaesthesia and paralysis in the foot-down position confers a high degree of protection from the aspiration of gastric contents. It does not appear to carry any obvious hazard from hypotension.

The technique is not difficult and causes only minimal delay and inconvenience to patient and staff. Therefore, it can be widely applied to cover all patients who are even remotely at risk. Table II indicates how widely the net of stomach emptying would have to be cast to achieve security.

Failure to omit any detail from the technique is fraught with danger and herein lies the principal objection to the method. Thus, a faulty laryngoscope, a leaking cuff, or failure to intubate, would all constitute a grave hazard. We would stress that this is not a technique for the tyro and it is difficult to exaggerate the importance of checking apparatus and equipment before induction.

We refrain from suggesting which might be the best method for anaesthetizing patients with full stomachs. The choice must depend upon a number of factors, many of which lie outside our experience. We would, however, maintain that, in our hands, the technique suggested by Morton and Wylie (1951) has been found to be satisfactory and safe.

SUMMARY

The problem of anaesthetizing patients with full stomachs is considered.

A technique of rapid induction in the foot-down position is described. This is essentially the method suggested by Morton and Wylie (1951).

We have used the technique for five years in a total of 606 patients considered to be at risk. In no case have we encountered aspiration of gastric contents.

ACKNOWLEDGMENTS

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ANAESTHETIC MANAGEMENT OF NEWBORN TO BE OPERATED FOR ATRESIA OF THE OESOPHAGUS

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CONGENITAL atresia of the oesophagus used to be a death sentence to the newborn, but since the first successful operation by Haight and Towsley (1943) the chances of survival after surgical repair of the malformation have been increasing steadily. This progress has been made as a result of the combined efforts of the obstetricians, paediatricians, surgeons and anaesthetists who deal with such cases. There are two indispensable requirements for success, viz., early diagnosis to make operation possible before complications occur, and therapeutic teamwork in the pre-, intra- and postoperative treatment of this condition.

In this team the task of the anaesthetist is by no means the least important as will become apparent in this paper which is based not only on the literature of this subject but also on the practical experience which has been gathered in 30 such operations, which were performed during the past ten years at the Second Surgical Clinic of the University of Vienna.

PATHOLOGICAL ANATOMY: INCIDENCE

It is believed that roughly 1 in 1,000 newborn babies suffers from oesophageal atresia of some sort. Zenker (1954) guesses only 1 in 2,500, but Belsey and Donnison (1950) and Sutherland (1951) think there may be even 1 in 800. The number of cases found has of course been increasing as obstetricians, paediatricians and even midwives have become aware of the condition and its better chances of successful treatment.

Wojta in 1956 collected reports on 355 cases in which surgical treatment was attempted and added 6 cases of his own. In the same year Humphreys, Hogg and Ferrer (1956) gave a report on 101 cases. I would guess that up to date in the whole world between 700 and 1,000 operations for atresia of the oesophagus have been performed since 1943.

TYPES OF THE MALFORMATION

A classical description of the different types of oesophageal atresia with oesophagotracheal fistula was given by Vogt in 1929 and his classification of the different malformations has been adopted as a standard. It is unnecessary to discuss in detail the pathological anatomy of the disease. Suffice it to say that in 85–90 per cent of the cases the type IIIb of Vogt is found. In it the dilated blind ending upper portion of the oesophagus reaches down into the posterior mediastinum, while the lower half of this organ has a direct communication with the trachea or one of the main bronchi.

Wojta (1956) thinks that this malformation develops during foetal life because an abnormally persisting double aortic arch strangulates the not yet completely developed oesophagus just above the bifurcation of the trachea.

ANAESTHETIC MANAGEMENT: SPECIAL PROBLEMS

Infants with atresia of the oesophagus very often also have other malformations. Frequently they are premature as well. As the condition usually is diagnosed only after the first few attempts at feeding, the children may already have aspirated foreign material into the lungs and come to the hospital in a more or less advanced stage of pneumonia.

The presence of a tracheo-oesophageal fistula requires special caution when artificial ventilation is employed either before or during operation. If the inspiratory positive pressure is too high, air may be forced through the fistula into the lower portion of the oesophagus and may lead to distension of the stomach and small bowel. We

take special precautions not to exceed 8 cm of water pressure and have found that this is sufficient for pulmonary ventilation and does not cause any disturbances.

PRINCIPAL REQUIREMENTS

The principal requirements for the conduct of anaesthesia in these cases can be listed as follows (Zindler and Deming, 1953):

Oxygenation must be adequate and the lungs must be inflated properly.

Efficient elimination of carbon dioxide must be secured.

The operation field should be properly exposed and reasonably quiet.

Normal circulating blood volume must be maintained by replacing blood loss as it occurs.

The airway must be kept clear at all times by removing blood or secretions from the tracheobronchial tree.

Normal body temperature must be maintained before, during and after operation.

The infants should recover immediately after operation without undue respiratory depression.

PRE-OPERATIVE MEASURES

In accordance with Gross (1955), Swenson (1958) and others, we do not now operate immediately on diagnosis of the malformation. On the contrary, it is believed that proper preoperative management increases the chances of successful surgical treatment. As soon as the diagnosis is established the following measures are taken by the paediatrician and anaesthetist respectively.

An intravenous infusion via a plastic catheter is set up. The neonate is originally overhydrated but it very rapidly becomes dehydrated when there is no normal fluid intake as in the presence of oesophageal atresia. The daily water loss of an infant is about 4 per cent of his body weight, which is twice the percentage lost by an adult. Correction of any existing dehydration in such tiny patients is therefore essential: 120–130 ml. per kg body weight are recommended and should be given over a 24-hour period. As do Stephen (1954), Smith (quoted by Gross, 1955) and others, we prefer 5 per cent glucose in water. Because of the relatively poor excretion of sodium chloride by the infant's kidney not more than 15 per cent of the total fluid replacement should be saline. Blood must be crossmatched and readily available.

Tracheobronchial toilet must be performed, gently but effectively. This is of utmost importance in all cases with commencing pneumonia. Pettersson and Haglund (1952) even recommend tracheotomy and gastrostomy to enable postponement of the main operation until the pneumonia has cleared up. The infants are kept in a moist chamber and oxygen is given to them, if necesary by intermittent positive pressure. The best method is to keep them in an incubator from the time the infusion is started until the beginning of the operation.

No pre-operative medication is given to these patients. Morphine and its substitutes and barbiturates depress respiration. Atropine increases the heart rate and may thicken secretions, thus causing postoperative respiratory difficulties.

THE ANAESTHETIC

When the infant—after careful pre-operative preparation—is brought to the operating room the next step is to place a flat stethoscope on the left side of the chest and fix it with a piece of adhesive tape. We have found this very helpful not only to listen to the respiration but also for the observation of the heart action, since this latter is a good guide to the baby's condition. Tachycardia may indicate too light anaesthesia, mild hypoxia or impending shock. All three conditions can be rectified quickly if recognized early enough. Bradycardia, on the other hand, is a bad sign, indicating either increased vagal tone or severe hypoxia, both of which may be followed by cardiac arrest if the surgical stimulus is not stopped immediately and the blood oxygen tension raised by gently inflating the collapsed lung.

Intubation in these newborn infants can be performed without any anaesthesia. A small dose of suxamethonium, however, facilitates the manoeuvre. We use freshly sterilized tubes, size 00 or 0, either the Cole type thin-walled rubber tubes or plastic tubes as devised by Loennecken with a bulge about 2 cm above the tip to prevent it from slipping down too deep. It is essential never to force a tube down the trachea. It should pass easily through the glottic opening since the narrowest part of the infant's

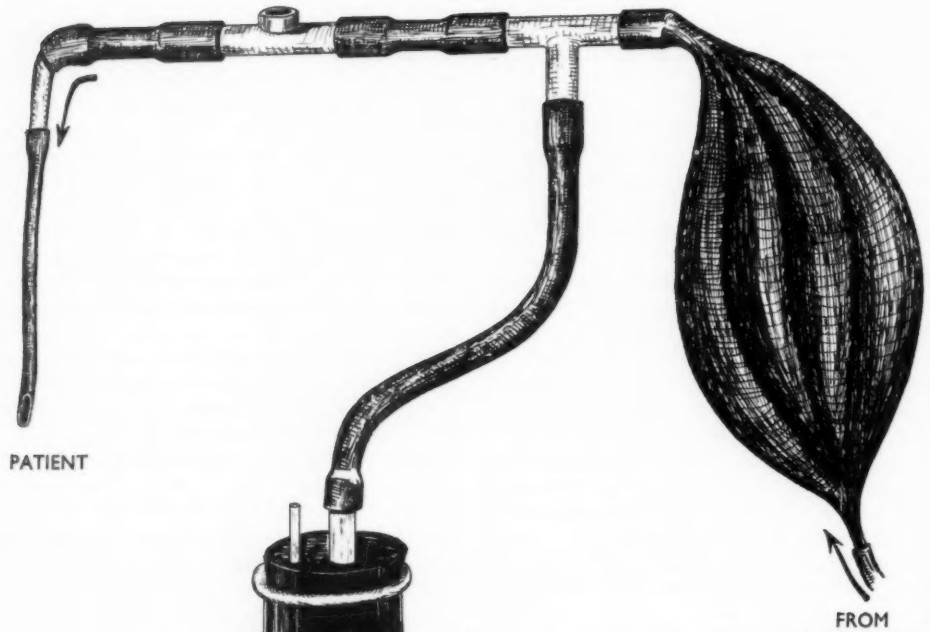

FIG. 1

larynx is below the vocal cords at the level of the cricoid cartilage. Trauma and bacterial contamination are the predominant causes for the much-dreaded laryngeal oedema following intubation in infants. With the technique described we were able to avoid this complication in all our cases.

The so-called "nonrebreathing" technique using the valve of Stephen and Slater (1948) has been used in these cases. To keep the inflation pressure low when assisting or controlling respiration a water lock is interposed between the valve and the rubber bag of the system (fig. 1). This method has two main advantages. Deadspace and resistance are minimal for the spontaneously breathing patient, allowing for easy escape of the exhaled carbon dioxide. Secondly, when the chest is open and respiration is taken over by the anaesthetist, the inflation pressure can be set at a fixed value (usually 6–8 ml of water) according

to the size and condition of the infant. Overventilation and trauma to the tender mucous membranes can thus be avoided.

Several anaesthetic agents can be considered useful and have been used successfully by different workers. We believe that the gaseous agents should have preference to ether, which we used in our early cases, since the gases allow a better minute-to-minute control of the depth of anaesthesia, and provide faster recovery. Cyclopropane is the agent chosen by most American and British authors (Smith (quoted by Gross, 1953); Zindler and Deming, 1953; Wilton, 1951). It has been used in only three of these operations, either combined with ether or with nitrous oxide. During the past five or six years we have gradually switched to using suxamethonium together with nitrous oxide for major infant surgery. This combination was first tried with the aim of eliminating the explosion hazard but it was soon found out that our tiny patients did even better than with the agents previously employed. Suxamethonium, as opposed to tubocurarine, is apparently well tolerated by children and infants. Single doses of $\frac{1}{4}$ to $\frac{1}{2}$ mg per kg body weight usually last between 3 and 6 minutes. For convenience the relaxant is diluted so that 1 ml contains 1 mg. The average dose for an infant is thus about 1 ml (Mayrhofer, 1958).

This method—intubation, Stephen-Slater valve, nitrous oxide, oxygen and suxamethonium, controlled respiration with low inflation pressure during the open chest part of the operation—has been used for the last twenty operations of this type. No disadvantage has become apparent which would prompt us to change our technique.

Blood loss must be replaced as it occurs. It is usually necessary to give 10–20 ml of blood rather early while the chest wall is opened since prevention of shock is easier than its treatment. Total blood loss in these operations is generally slight. The average in our cases was between 30 and 50 ml which we replaced in 5 ml portions by slow i.v. injection through the plastic infusion catheter.

The standard method of operation these days is the transpleural approach by opening the chest in the 4th or 5th intercostal space on the right side with the patient in lateral position. The tracheo-oesophageal fistula is divided between two ligatures and an anastomosis is performed either between the two parts of the oesophagus or between the upper blind sac and the stomach in one or two layers, using a small gastric catheter for a guide and prosthesis. After completion of the anastomosis the gastric catheter is removed and the lungs are fully inflated. When the chest is closed the patient is allowed to breathe spontaneously. At the end of the operation careful tracheobronchial toilet is performed and care is taken not to remove the endotracheal tube until the infant is fully awake and breathing well.

POSTOPERATIVE MANAGEMENT

In the postoperative period it is essential to keep the infants in a warm and moist atmosphere. In our institution they are immediately returned to the neonatal ward of the children's clinic and remain in the care of the paediatricians. The babies are kept in incubators; ample oxygen is given to them and the fluid therapy, which was started pre-operatively, is continued.

Oral feeding starts with drops of tea, not before the third postoperative day. Some surgeons (Gross, 1955; Humphreys, 1956; Swenson, 1958) recommend feeding through a gastrostomy, which should be performed under local anaesthesia 24 or 48 hours after the main operation. In our series this was only done in the last three cases, but the present surgical opinion is that it offers sufficient advantages to justify this second operation. The first oral feeding in these cases is given about 8–10 days after the main operation.

For prophylaxis and therapy of pneumonia the babies are frequently turned on to their sides and antibiotics are given. A suction device must always be at hand. It is most important to remove all excessive secretions from the oropharynx and, if necessary, also from the tracheobronchial tree.

COMPLICATIONS AND RESULTS

In our series the causes of postoperative death were usually complications which had already existed pre-operatively. None of the fatalities occurred during operation nor was any of them due to anaesthesia. As Zindler and Deming (1953), Gross (1955) and others point out, the mortality following repair of atresia of the oesophagus is largely determined by factors beyond the control of surgeon and anaesthetist. Among these factors

birth injuries, multiple malformations and prematurity accounted for half of the deaths in our series. Of the eight infants who died from pneumonia only one acquired this complication postoperatively; the others had it already before. We believe that increasing experience with these cases and, most of all, intensive pre- and postoperative care will improve the final results. The fact that of our first twenty-five cases only two survived, whereas of the five cases we treated during the past twelve months two survived, seems to indicate that we now are on the proper road to improve our results. Even Gross who in 1952 could already report a total survival rate of 47 per cent in 233 operations, lost twenty-three of his first twenty-five cases.

Early diagnosis, which comes from experience, and the team work between paediatricians, surgeons and anaesthetists, will continue to help saving more and more lives of these infants who only a few years ago were still condemned to death.

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THE BRITISH CONTRIBUTION TO BLOOD TRANSFUSION IN THE NINETEENTH CENTURY

BY

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AT the beginning of the nineteenth century the use of blood transfusion as a practical therapeutic aid lay discredited and almost forgotten in both Europe and America. The experiments of Dr. Richard Lower of Oxford (Gunther, 1932), started almost 150 years before in 1665, had stimulated widespread interest in the subject and many had copied his work. Principal among these was Denis, of Paris, whose first blood transfusion upon a human patient in 1667 anticipated that of Lower on the celebrated half-crazy Bachelor of Divinity, Arthur Coga, by only a short space of time. This new operation raised high and extravagant hopes of benefit to mankind; hopes recorded by Samuel Pepys in his diary (Braybrooke, 1906), but hopes which were, as yet to prove false. Lower and his contemporaries failed in part at least because of their ignorance and misunderstanding of the physiology of the blood and their misconception of the therapeutic role of blood transfusion. The belief was firmly held at this time that disease, both physical and mental, was associated with changes in the blood, and transfusion, after preliminary bleeding, was used to replace bad blood with fresh blood, thereby, it was believed, improving the state of the patient. So the madman was bled and then transfused with the blood of some docile animal, such as a sheep or calf, in the hope that he would take on the docile demeanour of the animal used. The senescent was similarly bled and his aged blood replaced in part by the blood of a young animal so that he might be rejuvenated. Not only was their conception of the role of transfusion incorrect but, in the light of modern knowledge, it was inevitable that the transfusion of animal blood into human patients must, sooner or later, end in disaster, and as a result of such disasters the operation was discarded.

There it was to remain for a century and a half until the animal experiments and findings of Leacock (1817) stimulated interest anew. From his investigations he formed the opinion that blood of the same species should always be used in transfusion and, further, he saw the operation as a means of saving life in severe haemorrhage, concluding: "The consequences of haemorrhages, where the functions are not dangerously affected, do not of course require transfusion . . . but when a parturient woman trembles on the brink of the grave, from a uterine haemorrhage; or when a soldier is at the point of death from loss of blood, what reason can be alledged for not having recourse to this last hope, and for not attempting to recruit the exhausted frame, and turn the ebbing tide of life." Leacock's first conception that only similar or homologous blood should be used was revolutionary and his second, that the principal indication for blood transfusion was the replacement of blood lost in severe haemorrhage, almost equally so, differing, as it did, so much from the practice of the seventeenth century.

A young London obstetrician of this time, James Blundell (fig. 1), was inspired by Leacock's work to investigate the subject himself. Born in London in 1790, Blundell became in due time a student at the United Hospital of St. Thomas and Guy and there included among his teachers his maternal uncle, Dr. Haighton, Lecturer in Midwifery and Physiology. He completed his training in Edinburgh, graduating from there in 1813, and returned to London the following year to become a Lecturer in midwifery in his uncle's department. He later succeeded to the Lectureships in Midwifery and Physiology at the United Hospital on the death of his uncle in 1818 and held these appointments until an unfortunate

FIG. 1
James Blundell, M.D., F.R.C.P.

dispute led to his resignation in 1834. He continued, however, to carry on a large and apparently lucrative private practice and died in 1878, leaving a fortune of over half a million pounds (*Brit. med. J.*, 1878). Blundell was appalled, like so many others, at the tragic loss of maternal life as the result of haemorrhage in childbirth. The treatment available early in the nineteenth century was more a matter of despair than of effective therapy. Ergot, though known since ancient times, was not used in obstetrical practice till 1807, when Sterns introduced it to the profession in America as "pulvis parturiens" (Thoms, 1931), but obstetricians in this country were denied its aid in the treatment of post-partum haemorrhage until nearer the middle of the century. Against this background of helplessness and tragedy in the face of haemorrhage, Blundell, searching for a means of effective treatment, adopted blood transfusion after careful preliminary animal experiments had placed it upon a more scientific basis. His work stimulated interest in the subject both at home and abroad. In this country he was the first of a long line of medical men, mostly obstetricians, who through the course of the century were to use blood transfusion either in the way he described or in a modified form.

His experiments (Blundell, 1818, 1824) showed that a dog bled almost to the point of death could be restored to active health by transfusing it with the blood of another dog, and further he demonstrated that if an exsanguinated dog was transfused with sheep's blood it usually died, even though the operation was attended initially with apparent recovery. A variety of methods of resuscitation after exsanguination were tried. First, transfusion from artery of donor to vein of recipient by means of a cannula. Second, by collection of donor blood in a vessel and its injection by syringe into recipient vein. Third, having satisfied himself that blood was not much vitiated by collection outside the vessels, he constructed an apparatus which incorporated a syringe for use in the transfusion of venous blood (fig. 2). This apparatus may well have been used for his earliest human transfusion and it certainly formed the basis for his later transfusion instruments. Like Leacock, he was convinced that for safe transfusion, blood of the same species must be used, saying "As it is clear from the preceding experiments that the blood of one sort of animal cannot with impunity be substituted indifferently and in large quantities for that of another sort of animal; it follows that in performing the operation of transfusion in the human body, the human blood alone be employed", and that the first and most important function of transfusion was to replace, in sufficient quantity, blood lost by haemorrhage. These experiments revealed how careful and painstaking an investigator Blundell was and with the work of Lower and Leacock constituted one of the first systematic researches in blood transfusions.

Actually, although primarily interested in obstetrics, the first case to whom he transfused blood was not an obstetrical one but that of a man "in extremis" suffering from "scirrhosity of the pylorus" and although there was transient improvement after 12 ounces had been given, the patient died. Blundell was not discouraged by this

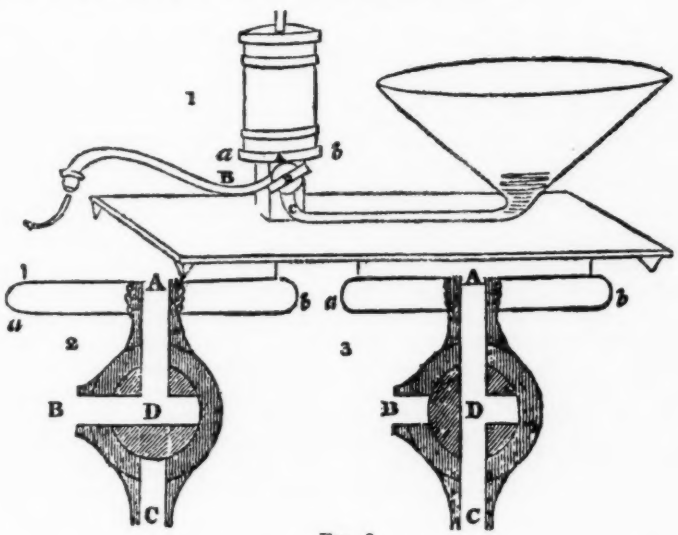

FIG. 2

Blundell's first transfusion apparatus.
1 exhibits the syringe, collecting cup, etc.
2 and 3 (below) show the structure of the two-way tap ADC

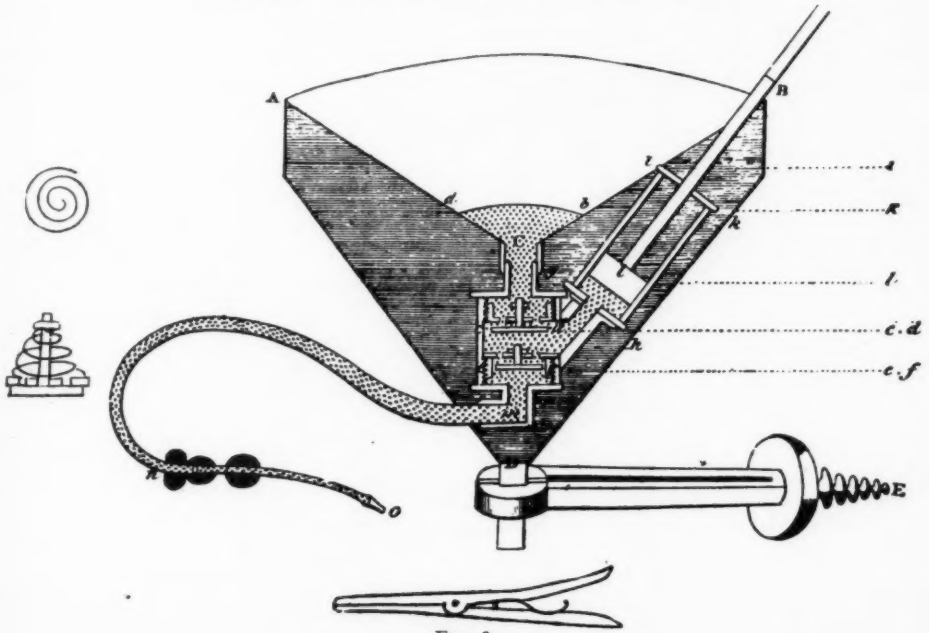

FIG. 3

The Impellor.

failure but continued experiments to perfect his apparatus, producing a new instrument which he named the "Impellor" (fig. 3). This consisted of an outer compartment (ADB) which formed a water bath surrounding an inner cup (C) for receipt of the donor's blood and a syringe (L). The water bath was filled with what Blundell described as "milk warm" water (96°F) and before use air was displaced from the tubing and cannula by pumping warm water through the apparatus. For the operation, the donor was seated in a chair, to which the Impellor was clamped (fig. 4). Blundell advised male rather than female donors, since they were less likely to faint and also bled more freely. To aid bleeding he advised the administration to the donor of a quantity of "spirit sufficient to arouse the circulation", but since it was often difficult, in spite of this, to obtain sufficient blood from one donor he liked to have a second and even a third available to add their blood if required. The Impellor appears unnecessarily complicated, but since it was thought that the admission of the smallest quantity of air might be attended with fatal results, Blundell's aim was to construct an instrument in which this would be impossible. Exposure of blood to air for even a short space of time and contact with foreign surfaces was thought at first to deprive it of its vital properties, but later, after the construction of the Impellor, Blundell modified his views and did recommend, both for portability and simplicity, the syringe as a means of transfusion, saying: "If it is hereafter shown that blood can lie in the cup for several seconds without becoming unfit for the vital purposes, transfusion by syringe may be used." Many members of the profession remained sceptical of the value of transfusion and many declared it

FIG. 4
The Impellor clamped to the chair.

dangerous. Of the latter, Blundell said (Castle, 1834a): "Against this operation it may be urged . . . that it is not without its danger; and it may be so. But this is no reason why we should lay it aside. As, then, every operation we perform is attended with more or less danger, unless it be proved, which it cannot, that the injection of blood is attended with more surgical danger than ordinary, why should we urge this as an objection against transfusion?"

Unfortunately, as was inevitable, reactions followed transfusions in some cases and although no fatalities were reported, the case of those opposing transfusion was greatly strengthened. In the absence of knowledge of haemo-agglutination, these reactions were for the most part attributed to contamination of the blood in its progress through the transfusion apparatus and in 1828 Blundell introduced the "Gravitator" (figs. 5 and 6) in an endeavour to reduce this risk, saying: "In the present state of our knowledge respecting the operation although it has not yet been shown to have proved fatal in any one instance . . . it seems right . . . to confine transfusion to those in which there seems to be no hope unless blood can be thrown into the veins. The object of the Gravitator is to help in the last extremity by transmitting the blood in a regulated stream from one individual to another with as little exposure as may be to air, cold and inanimate surface" (Blundell, 1828–9). Besides the risk of reactions or the injection of air into the veins, the transfusionist of those days, ignorant of aseptic techniques, had to contend with the not infrequent occurrence of thrombophlebitis in the arm of the recipient. In one case at least, Blundell applied leeches to the patient's arm after transfusion in an endeavour to prevent this complication.

Besides performing transfusion in his own private practice, Blundell was called to do so in consultation (Waller, 1825). Yet, although he was considered an authority on the subject it is probable that the total number of times he used this method was very small, since the operation was a rarity only used in desperate cases. Indeed, it was of such rarity and yet thought to be of such moment that it was not unusual in those days to publish the results of a single case. Soden (1852) was only able to collect thirty-five cases of blood transfusion carried out for obstetrical haemorrhage over the preceding twenty-seven years. These were taken from British, American and Continental literature. Jones and Mackmull

FIG. 5
The Gravitator.

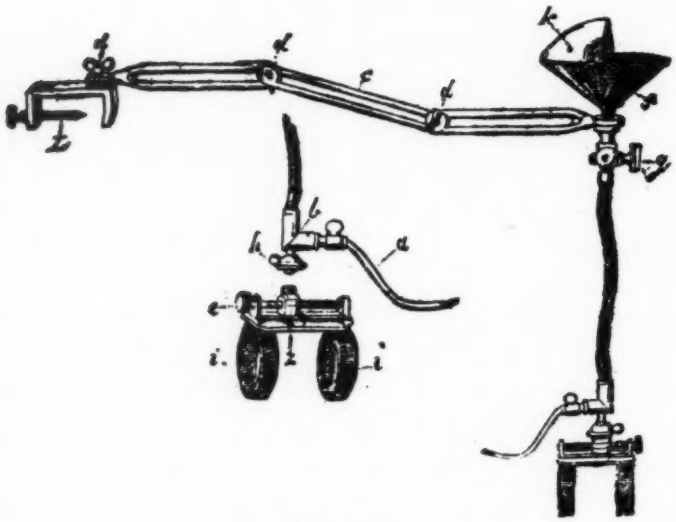

FIG. 6
The Gravitator.
i.i. are two pads on a spring-controlled extending arm z which grip the forearm and hold steady the intravenous cannula.

(1928), writing on Blundell's contribution to transfusion, state: "A careful search of the literature only revealed ten recorded transfusions performed by Blundell." Of these, five were described as successful, but of the remainder, one, his first case, was dying from cancer, two were probably dead before transfusion was commenced, and a fourth was suffering from puerperal sepsis. He taught that it was not necessary to replace all the blood lost to satisfactorily resuscitate a patient: "From what little I have observed, however, I should suppose that from half a pint to a pint may be considered as a very ample supply."

Blundell was the foremost obstetrician and gynaecologist of his time and a much respected teacher of physiology. A pioneer in the field of blood transfusion working in the face of considerable hostility and opposition from a section of his professional colleagues, he placed the operation on a sounder and more scientific basis than it had hitherto been, and what was particularly noteworthy, was the first to give warning of the danger of transfusing heterologous blood. There is little if any doubt that he was the first to use human blood for human transfusion. He became an eccentric in later life. It is said he never rose before midday, saw patients at home until 6 o'clock, dined and then set out on his round of visits which usually occupied him until midnight (Wilks and Bettany, 1892).

Contemporary with Blundell were two men who were quick to see the potentialities of this new method of resuscitation in severe blood loss and who collaborated with him in his work. These were Edward Doubleday, Surgeon to the Royal Infirmary for Children, and Charles Waller, who became Physician-Accoucheur and Lecturer in Midwifery at St. Thomas's Hospital. Of them, Blundell says: "When on the subject of transfusion I should be guilty of criminal injustice were I to forget to mention with applause the names of Doubleday and Waller. Their exertions stand in need of no commemoration from me, but I may be allowed to remark that whatever advantage may be hereafter derived from this operation, to them mankind will be largely indebted for it" (Castle, 1834b).

Doubleday favoured transfusion by syringe and his first case with a successful outcome, one

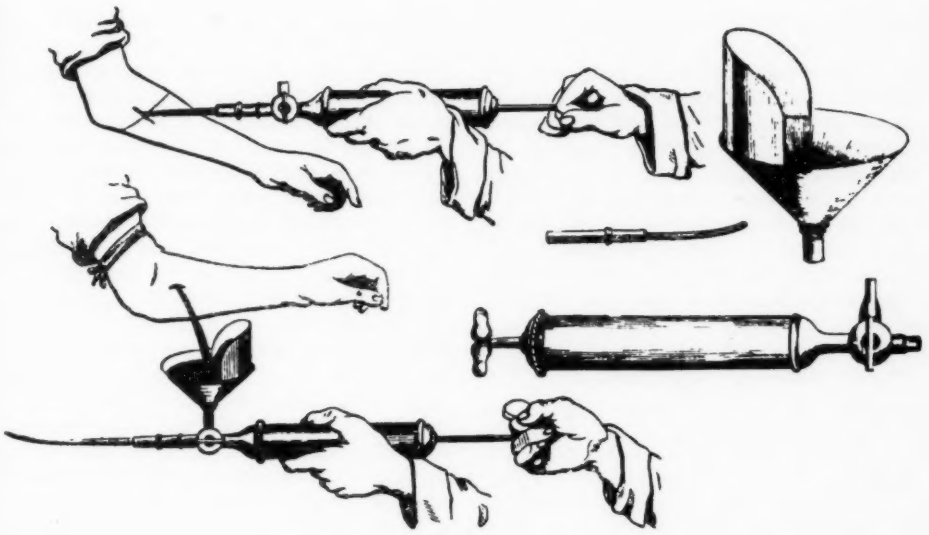

FIG. 7
Waller's transfusion apparatus.

of uterine haemorrhage, was reported in 1825 (Doubleday, 1825). Waller (1860) designed his own apparatus (fig. 7). This was much simpler in construction than either the Impeller or the Gravitator and consisted of a brass syringe, intravenous cannula with connecting tube, and collecting receptacle for the donor's blood. In theory it was possible with this apparatus, which before use was filled with warm water to exclude air, to carry out transfusion more rapidly and so reduce the time the blood remained in contact with the air, but in practice the main complication, which was common to all Blundell's apparatus too, was the tendency for the blood to clot and stop the operation. Like Blundell, Waller used transfusion with extreme caution, reserving it as a last resort in cases of severe haemorrhage. He believed it was seldom necessary to inject more than 4 ounces of blood to successfully revive a patient but thought that up to 12 ounces could be given with safety.

PART 2

Higginson (1871) presented an account of his experiences in thirteen cases of blood transfusion carried out by him in the period since 1848. This was certainly the largest series reported up to that time and, as far as can be ascertained, remained the largest in this country during the remainder of the century. Born in 1808, Higginson studied in Dublin and later went to Liverpool as Demonstrator in Anatomy at the Medical School there. He married Ellen, sister of Harriet Martineau the novelist. He became Consulting Surgeon to the Liverpool Dispensaries and from 1857 to 1867 was surgeon to the Southern Hospital, Liverpool. On his retirement he became Consulting Surgeon to this hospital, a post he held until his death in 1884. He is best remembered as the inventor of the enema syringe which bears his name. Careful search has failed to reveal any published description of this syringe or the date of its invention, but according to Brockbank (1954) the *London and Provincial Medical Directory* of 1852 describes him for the first time as the inventor of the elastic barrel enema syringe.

Of transfusion, Higginson says: "It appears that the effects of the operation have been such as to place its power and utility beyond question. It remains for future operators and observers to record faithfully their experience, to discriminate the class of cases to which transfusion is applic-

able, and to improve the operation itself, so as to avoid any imperfections and dangers still attached to it. . . . The blood being a vital fluid and losing its vitality quickly when withdrawn from the circulation there is need . . . that all delay, exposure and interference with it, in its passage to the patient should be avoided. It is also an absolute necessity to provide against the injection of air." The central rubber chamber of the enema syringe, which as originally designed was cylindrical in shape, was incorporated together with its ingenious system of valves in the transfusion apparatus designed and used by him (fig. 8). This consisted of: (1) a metallic cup, A, of six ounces capacity to receive the supply of blood; (2) an outer casing, B, to act as a water bath; (3) an elastic rubber barrel, E, of 1 ounce capacity; (4) a plug, H, to close the aperture, F, when necessary; (5) a rubber tube, G, ending in a metal intravenous cannula, O. Ball valves were provided, at D and F, capable of closing the upper openings when thrown against them, but leaving the lower openings always free. Describing the preparation to be made before transfusion, Higginson said: "Take a wash-hand basin nearly full of hot water, not less than 100°, and immerse in it the instrument and tube. Take out the screw C and fill the cavity B. Fill the tube G through to the opening at K and insert the plug." Ordinarily, when the blood had been collected, the cannula inserted into the recipient's vein, and all made ready for transfusion, the central barrel was squeezed once or twice and then "when the stream was well established the instrument acted by gravitation, requiring no assistance from the hand of the operator."

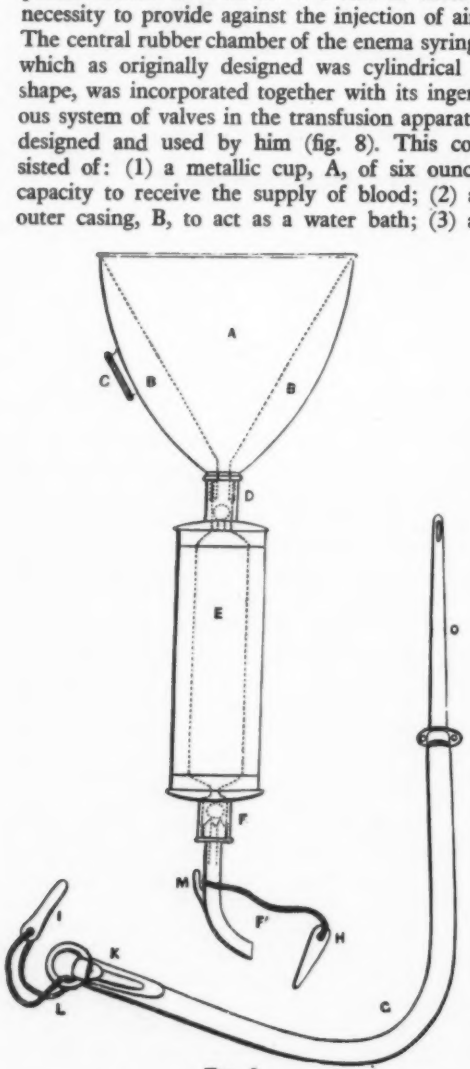

FIG. 8
Higginson's transfusion apparatus.

Of the thirteen cases described by Higginson, two occurred in his own practice and the remainder he was called to see in consultation. Ten of these thirteen cases were obstetrical, consisting of four cases of postpartum haemorrhage, three of placenta praevia, one adherent placenta, one abortion and one ectopic gestation, the last more euphemistically called Fallopian Foetation by Higginson. All these cases had suffered severe haemorrhage. Four recovered after transfusion. Of the remainder, one rallied to die a week later from infection, and in another there was a delay of several hours between haemorrhage and transfusion. The amount of blood given varied in these ten cases from 4 to 12 ounces. Since all these cases were almost certainly dying before transfusion, Higginson had good reason to be gratified that he was able to save four of them. Like all who practised blood transfusion at this time, he found coagulation the most troublesome complication and suggested that if this occurred "the operation can be completed with a syringe and teacup".

Although the frequent occurrence of coagulation must have been most irksome and frustrating to these early operators, it must have prevented many tragedies from incompatibility by restricting the use of the operation. It was fortunate, too, that small quantities of blood were considered sufficient for satisfactory resuscitation and that

the operation should be reserved for desperate cases only. Reactions did occur. An example can be found among the cases reported by Higginson. Mrs. C., aged 33, transfused for "extreme prostration from the protracted suckling of twins". He says: "The supply of blood was given by a female servant. It was estimated that 12 ounces were injected . . . but in a few minutes the patient was seized with a severe rigor. This was followed by a state of reaction and excitement in which she sang a hymn in a loud voice." Whether many proved fatal is impossible to say since such deaths would have been masked and ascribed to the low state of the patient. Had transfusion been easy and large quantities of blood given indiscriminately, the method would have been rapidly abandoned.

In an attempt to overcome the hazard of coagulation and to prevent exposure of the donor's blood to air, James Aveling (1865) made a simple apparatus for direct transfusion from donor to recipient's vein (fig. 9). Aveling graduated from Aberdeen University and came south to begin his career as obstetrician and gynaecologist in Sheffield. While in this city he was instrumental in founding the Hospital for Women and became a member of its staff. Moving to London in 1870, he founded, with Barnes and Chambers, the Chelsea Hospital for Women and served upon its staff as Physician (*Lancet*, 1892). He called his method of transfusion the immediate as distinct from the mediate method which had up to then been in use. The apparatus consisted of "an indiarubber tube to form an anastomosis between emittent and recipient veins with a small bulb in the middle to act as an auxiliary heart". The anastomosis was completed by silver intravenous cannulae. Aveling reported seven cases transfused with this apparatus. One of these was upon a patient whom he had been called to see in consultation in 1872 after she had suffered a very severe postpartum haemorrhage. He found her without a palpable radial pulse and with dilated pupils which failed to react to light. An immediate transfusion was made, using the family coachman as donor, and the patient made a good recovery (fig. 9). Reporting this case, Aveling says: "The coachman, who was not only collected and cheerful, was able to make several useful suggestions during the process of the trans-

FIG. 9
Aveling's transfusion apparatus.

FIG. 10
Aveling's modified apparatus.

fusion." He claimed, quite correctly, that his new apparatus was simple, inexpensive, effective and portable and "capable of being carried in the pocket". He gave as advantages of the immediate method the smaller risk of coagulation and the protection of the blood from air, and concluded: "The operation is safe, easy, uninterrupted and a close imitation of nature." After experience gained in the case described above, Aveling modified his apparatus to include a stopcock at each end to make the propulsion of blood to the recipient more positive (fig. 10).

A contemporary of Aveling's, Graily Hewitt (1865), Assistant Physician-accoucheur at St. Mary's Hospital and later Professor of Midwifery at University College, introduced an apparatus (fig. 11) in which the barrel of the syringe was used as the receptacle for collecting the donor's blood. Of it, he said: "The method allows the almost instantaneous transference of the blood from one individual to another and exposure which, as is well known, tends to produce rapid coagulation, is reduced to a minimum. This is effected by making the syringe itself the vessel into which the blood is received." The syringe with its adjuncts of cannulae, scalpel, etc., were put up in a carrying case and Hewitt advised that it "be carried in the obstetric bag, being thus always at hand in case of emergency."

In an attempt to prevent coagulation of blood during transfusion Braxton Hicks (1869),

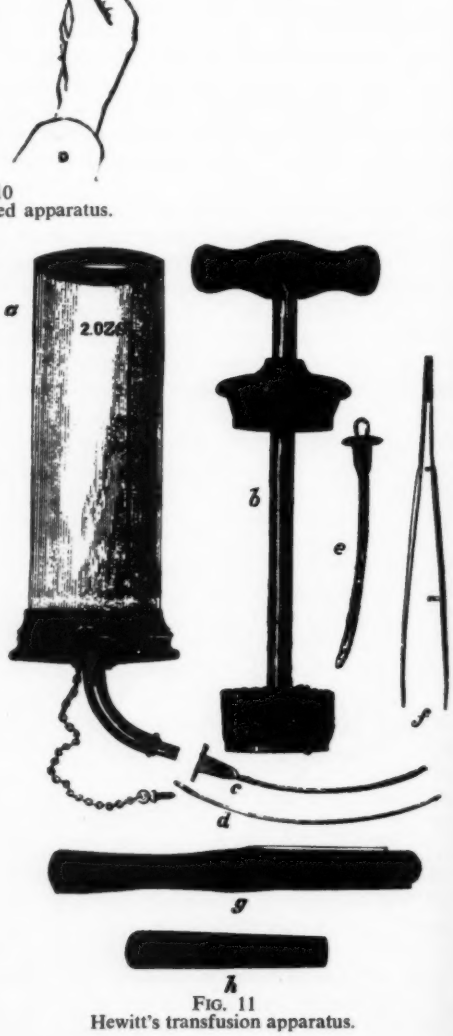

FIG. 11
Hewitt's transfusion apparatus.

Obstetric Physician and Lecturer in Obstetrics at Guy's Hospital, described the use of an anticoagulant. Seeking for a suitable substance to add to the donor's blood, he was advised by Dr. Pavy, Assistant Physician to Guy's Hospital, that phosphate of soda "would be the best tolerated". After satisfying himself by animal experiment that blood so treated appeared safe, Hicks used the method to treat four obstetrical patients. Unfortunately all four cases died, but reading the case histories of these unfortunate women it is too plainly obvious that they were already moribund and beyond aid when transfusion was commenced. Indeed, the indications for transfusion given by Hicks show how low the patient was allowed to sink before recourse was made to the operation for he says: "Perhaps the symptoms on which I should rely most are the obstinate jactitation and resistance to comply with our wishes in regard to treatment coupled with the persistent indistinctness of the pulse." His solution was prepared by dissolving 3 ounces of phosphate of soda in 1 pint of water. The solution, which crystallized out at room temperature, was warmed to 100°F before use and added to the blood in the proportion of 1:4.

This new technique, which simplified transfusion considerably, appears to have been widely adopted. It was introduced to Edinburgh by J. M. Cotterill (1884), Assistant Surgeon to the Royal Infirmary. After describing its use with complete success, first in a severe haematemesis and later in a blast injury which required four transfusions, he said of it: "There can be little doubt that the operation of transfusion is one which in the future is destined, in our Edinburgh School, at least, to hold a far more prominent position than it has hitherto done. This is due to the fact that the method of operation has been simplified and perfected: the applicability of the operation to various classes of cases increasing in the same proportion as the recognition of the ease and safety with which it can be performed. It is somewhat remarkable that this method has not come into more general use, as it certainly deprives the operation, as usually performed, of most of its difficulties and dangers."

Another member of the surgical staff of the Edinburgh Royal Infirmary, John Duncan (1886), also used this method. In dealing surgically with injuries, particularly those requiring amputation, it was his practice to collect the blood shed from the wound during operation in a bowl containing Hicks's saline solution. At the end of the operation, when all bleeding points had been ligated, this blood was re-injected into a vein. Duncan advocated this method since it removed the need to find a donor, often at short notice. He was unaware that he was removing the danger of incompatibility.

To overcome the difficulty and danger of coagulation some advocated the use of defibrinated blood. The method entailed whipping the blood with a wire whisk or glass rod after collection in a suitable vessel and later straining through a horse-hair sieve to remove small pieces of fibrin which had not adhered to the whisk. It was time-consuming and this was a particular disadvantage in an operation which was usually one of very extreme urgency. Among those who used the method was Robert McDonnell (1870), Surgeon to Dr. Steevens' Hospital, Dublin. He claimed that once the fear of coagulation was removed the need for haste and the risk of embolism vanished. He was satisfied that all the important elements, "the serum, salts, blood discs and vivifying agents" were preserved and further that "nothing was left out save what is physically useless if not injurious and surgically dangerous". He acknowledged that the time lost in defibrination was quite unjustifiable in cases requiring urgent transfusion and suggested the use of Hicks's anticoagulant solution in such cases. He designed a simple form of apparatus (fig. 12). This consisted of a glass pipette, ABC, of such size that the bulb, C, was capable of holding 6 ounces of blood; a length of rubber tubing, D, with a glass insert, F, to detect the passage of air bubbles, and a silver intravenous cannula. McDonnell noted that the weight of the column of blood was usually sufficient to carry it into the recipient's vein but added that if the flow was sluggish "the mouth could be applied to the end, A".

W. S. Playfair, Professor of Osbtetric Medicine in King's College, also advocated defibrination of the blood. Reporting the use of transfusion in a case of postpartum haemorrhage (1872) he says: "In considering the lessons to be learnt from this case, the most important seems to me to be the further evidence is gives

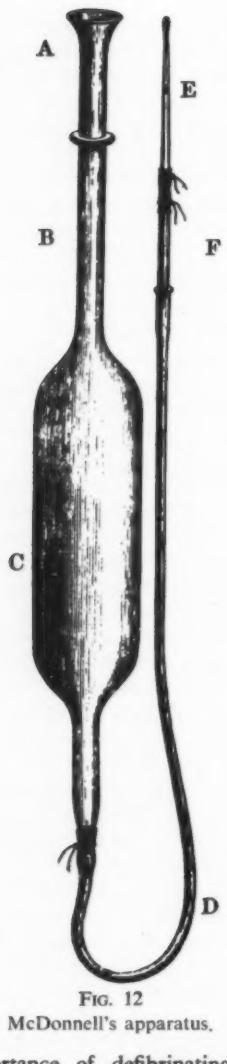

FIG. 12
McDonnell's apparatus.

of the importance of defibrinating the blood before commencing the operation. The process by which this is effected is extremely simple and the fact of not being hurried . . . is of immense importance in an operation every step of which should be conducted leisurely and calmly. It is certain that the removal of the fibrine does not in any way deteriorate the blood for the purposes of transfusion."

William Walter (1885), Surgeon to St. Mary's Hospital for Women and Children and the Manchester and Salford Lying-in-Hospital, produced a modification of McDonnell's apparatus (fig. 13). He described it as consisting of "a glass tube sufficiently large to hold four ounces of blood. One end of the apparatus was drawn to a point for the purpose of connecting it to a piece of india-rubber tube, which in form resembled a very small Higginson's syringe." The blood sometimes flowed by gravity into the recipient's vein but if it failed to do so it was necessary to force the blood into the vein by squeezing the dilatation in the tube.

The several methods of transfusion available, together with the variety of forms of apparatus for performing the operation may well have been responsible for the decision of the Obstetrical

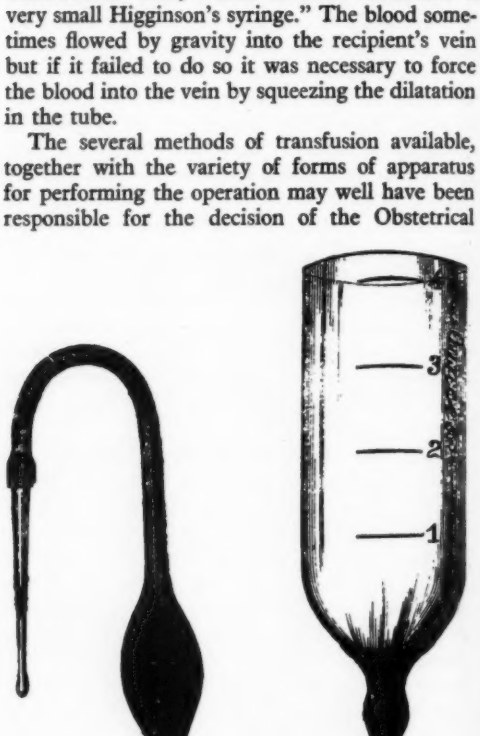

FIG. 13
Walter's transfusion apparatus.

Society of London (1872) to set up a committee to investigate the subject. John Hall Davis, Obstetrical Physician to Middlesex Hospital was elected chairman and Henry Madge the honorary secretary. The committee appears of have remained in being until 1878, but although a very careful search of the *Proceedings* of the Obstetrical Society and of the contemporary journals has been made, no report can be found. Apart from the announcement of its formation, the only reference to its deliberations was made by Madge (1874), when he reported upon the scope of the committee's work and appealed to those with experience of transfusion to submit their findings. This committee must have accumulated a wealth of information concerning both the current views of the operation and the types of apparatus available. It is regrettable that its findings, which would have been of the greatest historical interest, were apparently never published.

Transfusion had commenced in the days when the meaning of asepsis was quite unknown and the impact of Lister's teaching is to be seen in the report of a case by William Macewen (1879), Surgeon to Glasgow Royal Infirmary, entitled "The Antiseptic Transfusion of Human Blood in a patient the Subject of Secondary Haemorrhage: Cure". The arms of both donor and recipient and the carbolized collecting vessel were kept constantly under the carbolic spray and the blood was drawn into a carbolized syringe for transfusion.

As the century drew to its end the profession's views on transfusion changed radically. The transfusion of simple saline fluid, first described as early as 1848 by Spencer Wells, was being used more and more as a method of resuscitation in blood loss and shock. It was believed to be as efficacious as blood; it was certainly easier to use and when viewed against the background of more frequent fatalities consequent upon the more widespread use of blood transfusion, it seemed so much safer. The current views were probably expressed by William Hunter (1889) in the Arris and Gale Lectures at the Royal College of Surgeons of England, who said: "The question as to the value of transfusion seems ever to remain an open one . . . the present attitude of medical opinion may be described as one of healthy scepticism." He discussed the physiological and pathological problems presented by blood transfusion, noting that it was necessary to find an explanation for the disturbances such as dyspnoea, tachycardia, syncope, etc., frequently encountered. Mentioning the use of sodium phosphate, he emphasized the opinion that many of the symptoms, now known to be due to incompatibility, were caused by the addition of this salt. He summed up his lecture by saying: "If there is a threatened failure of the circulation as a result of sudden loss of blood, then it is unnecessary to have recourse to blood transfusion as infusion of any neutral saline meets equally well if not better all the indications. . . . In an emergency the infusion of ordinary water has been followed by results as successful as any ever obtained by transfusion of blood. . . . Transfusion of blood will continue to be practised . . . for practical purposes, however, all the advantages to be gained by it may, I believe, be equally well and more readily obtained by infusion of neutral salt, such as 3/4 per cent common salt."

So the nineteenth century was destined to end as it had begun, with blood transfusion in eclipse, but fortunately for mankind it was an eclipse of short duration. It is interesting to speculate on the part, if any, men like Blundell, Doubleday, Waller, Higginson, Aveling, Hicks, McDonnell, and the many others who practised blood transfusion, played in bringing to fruition the operation as we know it today. That they were instrumental in saving the lives of some few patients cannot be denied, but viewed in retrospect their achievements appear to bear little relation to the present-day practice of blood transfusion. Yet, however small, it is pleasant to believe that their exertions were but part of the eternal pattern; part of the tide of progress. In the words of Arthur Hugh Clough:

"For while the tired waves, vainly breaking,
Seem here no painful inch to gain,
Far back, through creeks and inlets making,
Comes silent, flooding in, the main."

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CORRESPONDENCE

Sir,—I was interested in your editorial for August pointing out that we should be vigilant in maintaining the exact sense of words.

We are indeed prone to supineness in this respect.

C. LANGTON HEWER

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